

Fun experiments in ELECTRONICS

EXPERIMENT MANUAL

by Hanna Hock



Logix-kosmos

SCIENCE FUN
EXPERIMENTS IN ELECTRONICS

ASSEMBLY AND
EXPERIMENT MANUAL

by Hanna Höck

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Published by
LOGIX ENTERPRISES LTD.
736 Notre Dame Street West,
Montreal, Canada

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FRANCKH'SCHE VERLAGSHANDLUNG, KOSMOS
Stuttgart, West Germany

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Printed in Canada

INTRODUCTION

Now that you have opened your science kit and examined the contents, you are ready to begin constructing your own console and doing the experiments.

Electronics is a major subdivision of electrical science. As the word "electronics" itself suggests, it studies the behaviour of electrons.

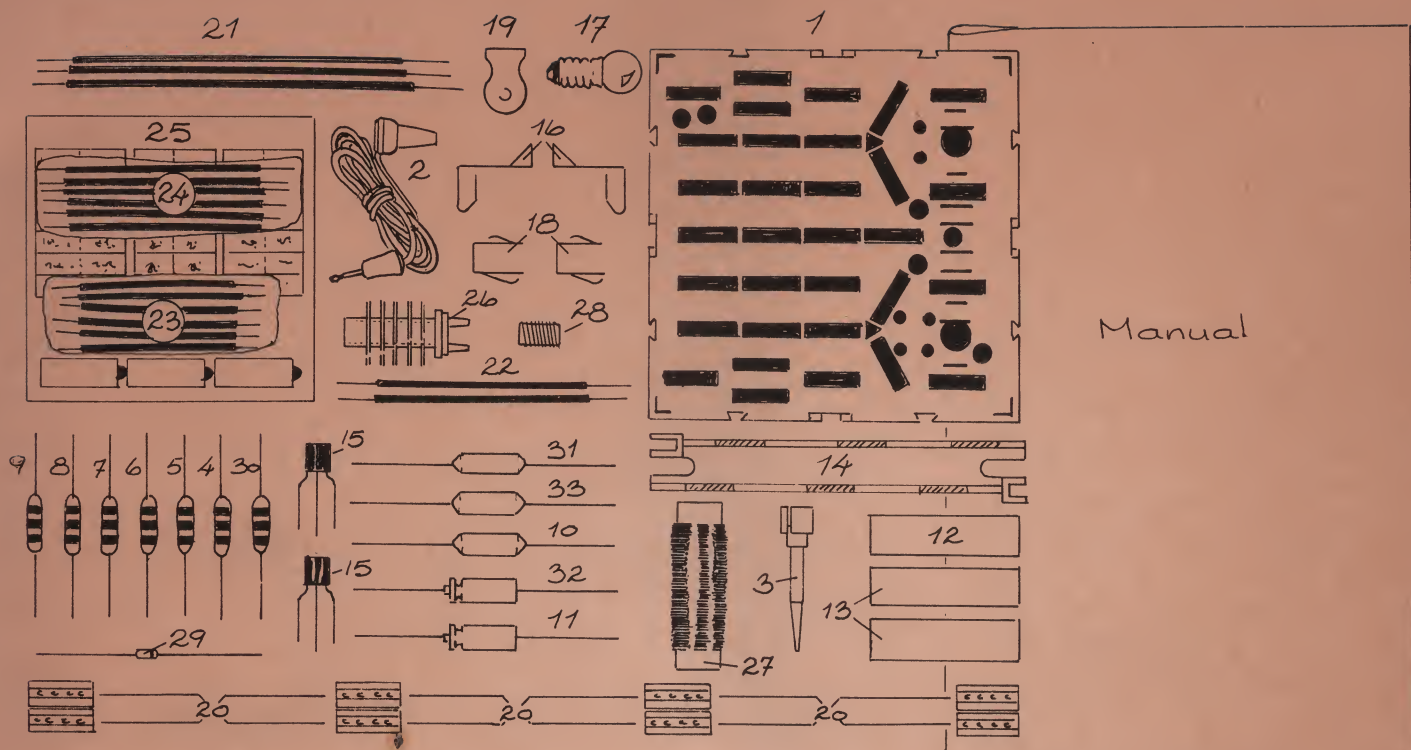
Electrical current is actually a flow of electrons, and many of the principles used to control electricity are explained in the science of electronics. In the course of experiments in this kit, you will learn some of the basic methods used to put electricity to work in our modern world.

One word of advice--follow the experiments one by one! Don't skip any, since they become progressively more difficult. Understanding a new experiment often depends on having done the one which comes before it.

Above all, have fun with your kit as you enter the fascinating world of modern electronics!

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The experiments require three AA 1.5 V dry cells which are not included in the kit due to their limited storage life. The shapes and electrical values of capacitors supplied in the kit do not exactly correspond with what is shown above. However, they function just as well in the actual circuits.

#1. HOW TO GET STARTED IN ELECTRONICS

This kit will show you how to make a signal light, a morse code sender, a buzzer, a siren, and other things you probably want to build right away. If you learn to read the diagrams, you should have no trouble making any of them.

It will be easier for you if you start from the beginning and go in order. To get the most help from the diagrams, take a colored pencil and mark over every connection shown on a diagram after you have actually made it on your console. This way you will notice immediately if you have forgotten to make some connection.

If you have trouble with a new circuit, it's most likely that you have made an error in connecting it. If you suspect that a part has been damaged or burnt out in a previous circuit, you can check it by rebuilding the first circuit in which it worked. If testing in this manner shows that a part is broken, write to us for a replacement (price list included). We will consider problems you have connecting any circuit. Remember that each one has been built many times by other people and has worked for them, so they will work for you as well!

#2. BUILDING YOUR CONSOLE

You will find a diagram at the beginning of the book which shows all the parts of your kit as they are packaged in the box. Each part has a number, and the list at the bottom gives you their names. We will mention the number of each new part when we use it for the first time.

Checking the snap clips

All the connecting wires in the kit have bare ends, which can be inserted into the small holes on the tops of the snap clips. Take a snap clip (20) and look at it. Press it together gently and push it halfway into one of the slots in the console, as shown in diagram 3.

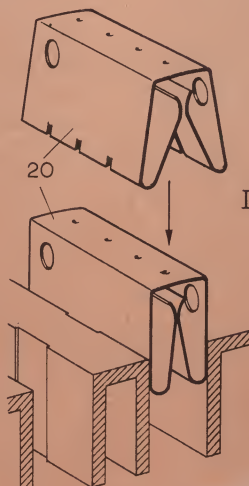


Diagram 3. Snap clips

Inserting the wire into the snap clip

Now insert the bare end of a long wire (21) into the snap clip and watch how the wire pushes the clips inside apart. The wire must be pushed far enough between the clips until they hold it in place firmly.

You should be careful to insert the ends of the wire at an exact right angle (upright) into the clips, so they won't be damaged. You should be careful when you take them out, as well. Pull them out straight, or they may bend.

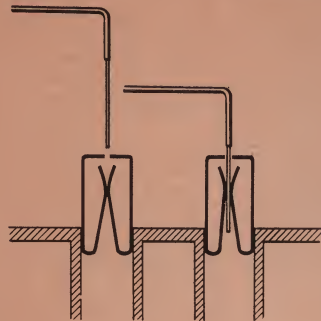


Diagram 4. Inserting wires into a snap clip

Practice putting the wires into the clips a few times before you press the clips all the way into the console. This will help you to avoid difficulties during real experiments.

Now we will refer to the snap clips simply as "clips".

Inserting the snap clips

Now push the clip all the way into the console. Notice how little pegs on the sides of the openings in the console snap into the holes in the sides of the clip.

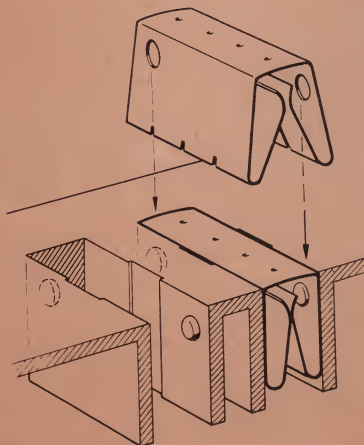


Diagram 5. Inserting a snap clip

Snap the rest of the clips into the console in the same way. At the end you should have a flat surfaced console before you, on which each clip is marked with a number. When talking about a clip we will always refer to its number.

Battery contacts

Turn the console upside down and take the two battery contacts (16). These will later make contact between the battery and the clips. Put the pointed end of the contacts into the slots in which clips 15 and 79 are resting, so that the curled end reaches into the corners of the console. Diagram 6 will give you some help.

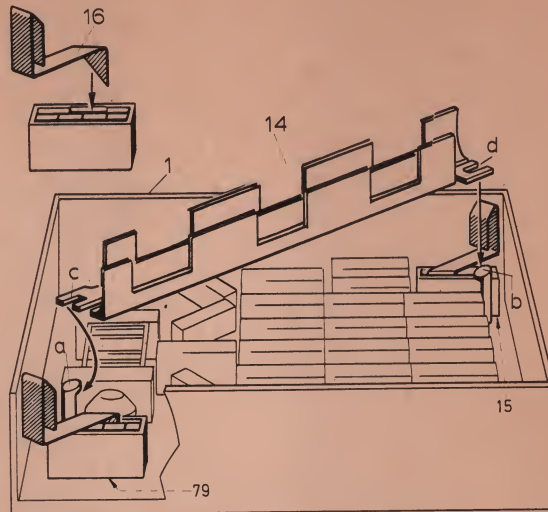


Diagram 6. Building in the battery holder

The battery holder

The battery holder (14) will contain three cells. Lay it flat side down into the interior of the console, so that the projecting fork ("c" in diagram) slides around peg "a". Press the other end of the battery holder firmly so that the fork "d" snaps around peg "b". The battery contacts are now held firmly under the battery holder.

Take the label with a series of boxes and plus - minus signs on it from the label sheet (25) and press it onto the battery holder so that the first plus sign points to clip 15, and the last minus sign to clip 79. This label will help you to place the cells correctly.

Inserting the cells

Now insert the cells into their holder. Together these cells will work as a battery. They each have a positive pole (marked +) and a negative pole (-). The positive pole of the first cell must lie with its cap directly on the battery contact at clip 15 (see diagram 7). Its negative pole should touch the second cell's positive pole, and the second cell's negative pole should touch the third cell's positive pole.

That brings a negative pole against the battery contact connected to clip 79. To put the cells in, lay them one by one in the groove of the battery holder and press them firmly until they snap into place.

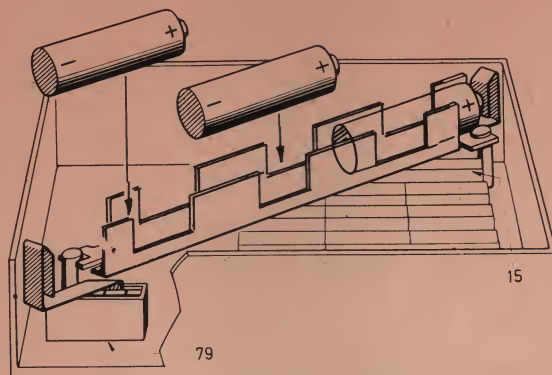


Diagram 7. Inserting the cells

To change the cells

Your utility tool (3) can touch one of the cells through hole "e" in the top of the console. Push the cell out of the battery holder by applying pressure to it through the hole. The others can be removed by sliding them into position beneath the hole and doing the same thing.

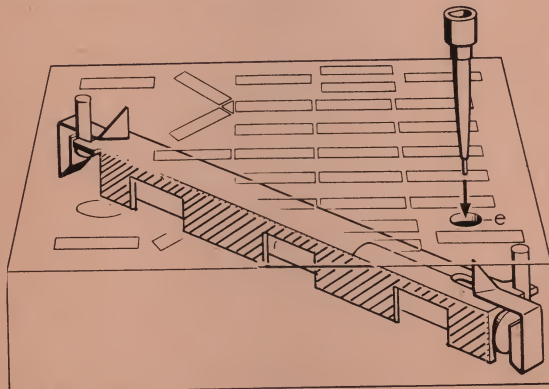


Diagram 8. Changing the battery cells.

On the top of the console you will notice small square indentations near clips 15 and 79. Take the positive and negative signs from your label sheet (25), and press the positive (+) sign into the indentation by clip 15, the negative (-) near clip 79.

Now you are ready to begin experimenting!

#3. HAVE YOU CONNECTED EVERYTHING PROPERLY?

You should now check to make sure that in assembling your console you didn't make a mistake. Take two long red wires (21) and the light bulb (17). Insert one wire into clip 15 near the positive pole, and one into clip 79 near the negative pole. Do not allow the free ends of these wires to touch one another or the electricity will flow directly from the positive to negative pole, quickly draining your battery in what is known as a "short circuit". Now touch the stripped end of one wire to the metal screw casing of the bulb, and touch the stripped end of the other wire to the metal knob on the casing bottom.

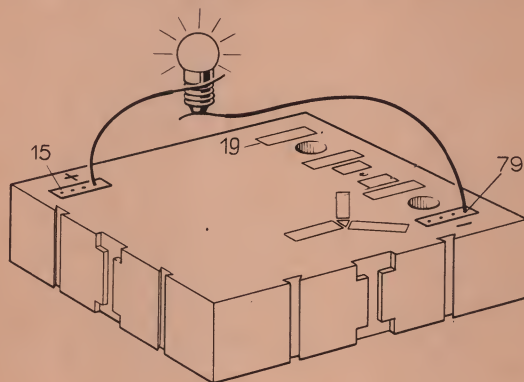


Diagram 9. Checking the construction

Does the bulb light? If it does, everything is in order. Otherwise you'd better check to see if you placed the cells in the right order, and whether they touch the battery contacts properly.

#4. MOUNTING THE LIGHT BULB

We will now use the two bulb connection wires (22) to make electrical contact in the bulb socket (marked La on your console).

Turn your console over. On the socket wall you will notice two pairs of holes, one pair on its bottom and one pair closer to the base of the console. Thread one wire end into one of the bottom holes and out the other bottom hole; bend the tip of the wire to secure it firmly. Now thread the other end of the wire through hole "d" so that it comes through on top of the console.

The other bulb connection wire is threaded with one bare end entering the socket through one hole close to the base of the console and leaving it through the other base hole. The tip is bent to secure the wire in the socket. The long end is

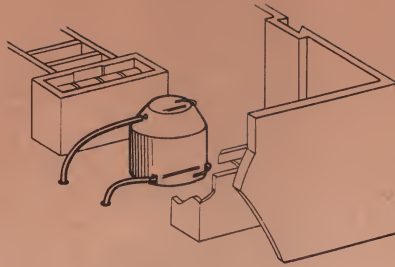


Diagram 10. Bulb socket from below

threaded up to the top of the console through hole "c". If you have difficulty with these threading operations, use your utility tool (3) .

Now connect the wire in hole "c" to clip 19, and the wire in hole "d" to clip 39.

Make sure that the two wire ends make no contact in the lamp socket. If they do, there will be a short circuit. Then the lamp would not light up; the electricity would flow directly from the positive to the negative pole, bypassing the bulb, and in short time your battery would be empty.

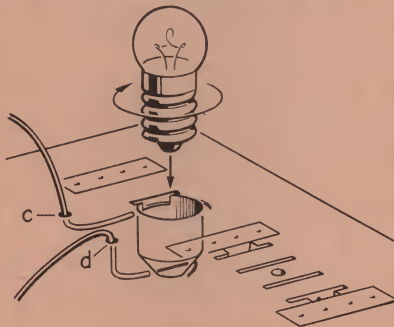


Diagram 11. Screwing in the bulb

#5. A LIGHT TEST

Screw the light bulb firmly into the socket. Now attach the lamp wire from the positive pole to clip 19, and the wire from the negative pole to 39. The bulb should light up.

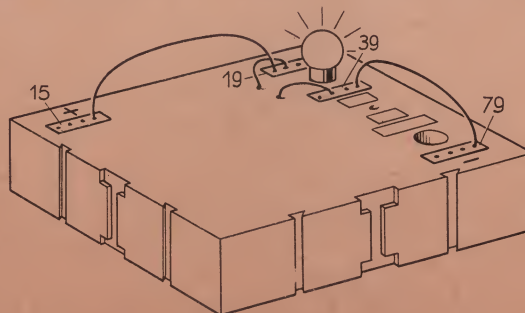


Diagram 12. Testing the bulb

#6. SWITCHING THE LAMP ON AND OFF

The electricity flows through the wires to the bulb. When you disconnect one of the wires, the bulb goes out. At how many points can you switch off the light? Try and see. As soon as you connect a wire once again, the bulb will light up. The bulb will light even when you just touch a clip with the right wire rather than sticking it into the hole, because all parts of the clips are able to pass electricity on - that is, they are able to conduct electricity.

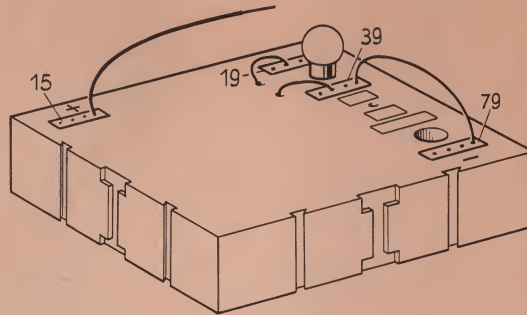


Diagram 13. Switching off the bulb

The way you are turning your little bulb on and off is the same in principle as the way the light in your room is operated. The major difference is that what you have before you on your console, which is called a circuit, is much smaller than the circuit that brings power from the electrical plant to the light switch and finally to your lamp.

Now let's take a closer look at circuits.

#7. CIRCUITS

One could compare an electrical circuit with a water system. Water runs from the tap in a jet or drop by drop, depending on how much you turn the tap. It runs out of your sink, back to rivers and lakes, and then is pumped into water towers by huge pumps. The height of the water towers is important because it affects the pressure with which the water is forced into pipes. When you turn off the tap, the water circulation to your home is stopped.

Electrical current is made up of tiny parts called electrons. You can't see them like you can see drops of water, and they are able to move only on set paths: we call this path or system of paths a circuit.

When you look at your console with the burning light, the connecting wires and the cells in the battery holder, you are looking at such a circuit.

In the negative pole of the battery, the electrons are waiting

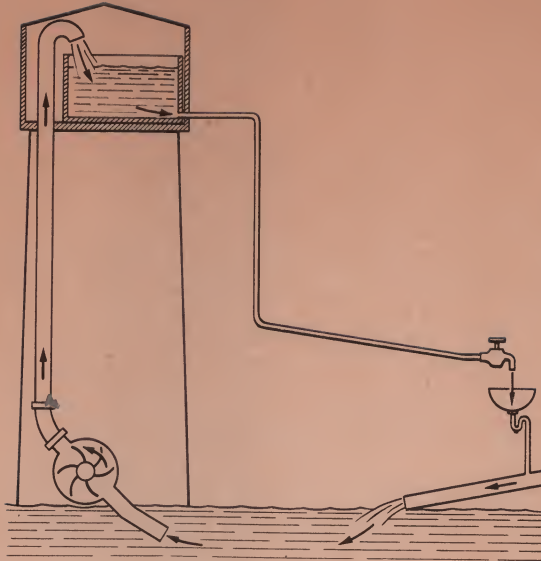


Diagram 13. Water circulation

to enter the wire. In the wire which is protected by insulation, the electrons can move very easily. Nothing disturbs them as they go on their way. But the light bulb poses a problem. The thin wire that lights up in the bulb (called the filament) doesn't let the electrons by so easily; they have to make an effort to overcome the resistance from this wire. Because the electrons have to use so much energy, the filament in the bulb gets hot and glows. Afterwards, though, the electrons continue easily along the other wire back to the positive pole. This pole was waiting for them and sucks them up. After the electrons have travelled through all three cells, the circuit is finished.

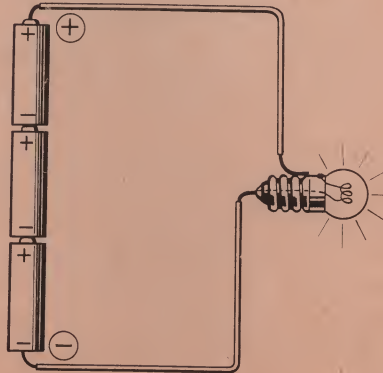


Diagram 15. Electrical circuit

#8. DIRECTION OF ELECTRICAL CURRENT

The scientists who worked with electricity a hundred years ago didn't know anything about electrons. They only knew that there were positive and negative poles, and that the

electricity flowed between them. They weren't sure in which direction it flowed, but they took a guess for convention and said: the current moves from positive to negative.

But make sure you understand: although we still say that the current flows from positive to negative, the electrons themselves really flow from negative to positive. In our manual, as in other technical books, we still assume, as the older scientists did, that the current flows the other way.

#9. ELECTRICAL POTENTIAL

The height of a water tower is very important for the circulation of water. The greater the drop between a water tower and the distant watertap, the greater the pressure which makes the water flow. You'll always find water in the pipes, but it doesn't flow until pressure is applied.

An electrical circuit is similar to this. There are always electrons in wires, but they can't flow as electricity until pressure forces them through.

Electrical pressure is called potential or electromotive force. There is electrical potential between the poles of the battery from whose negative pole the electrons are flowing. The electrons travel over the connecting wire, through the light bulb, to the positive pole, where the battery absorbs them again.

An expert measures potential with a voltmeter, an instrument which indicates in volts the potential between the two poles. One could say, for example, that the cell has 1.5 volts (abbreviated to "V") electromotive force (e.m.f.).

The tension is increased by connecting a number of cells to make a battery. In our battery holder are 3 cells. When we add the tension of these 3 together, we find out we have an e.m.f. of 4.5V between our battery contacts. So in all our circuits we are working with a 4.5V potential.

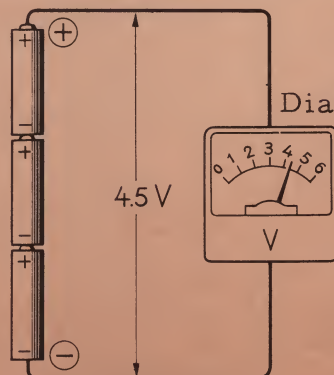


Diagram 16. Potential in volts

#10. CHECKING FOR CONDUCTION

Electricity is able to pass through some materials, but is unable to pass through others. Those which allow electricity to flow through themselves are called "conductors"; those which do not are called "insulators". Let's test different materials to find out whether they are conductors or insulators.

The lamp wires are connected to 19 and 39. A long wire connects the positive pole with 19, and a second long wire is attached to 39. Now we connect a third long wire to the negative pole (see diagram) .

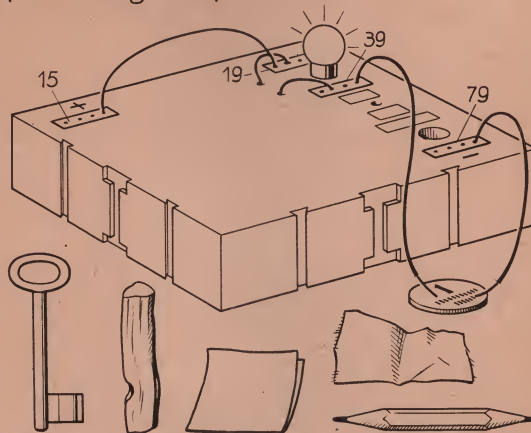


Diagram 17. Testing for conductivity

In this experiment the light bulb will be our "indicator"; that is, it will tell us if electricity is flowing. Before we begin the experiment, let's check to make sure that the console is in order. Hold the loose ends of wire from 79 and 39 together. Does the bulb light up? Then everything is fine. Otherwise, look for a mistake. Perhaps a wire isn't pushed into a clip properly, or the bulb is loose. Are the batteries firmly in place and do they touch the battery contacts?

Now place a coin on the table and hold the loose ends of wire 79 and 39 to it making sure the wires do not touch one another. The bulb lights up. Test to see if a key lets electricity pass through it. You will see that all metals allow current through (we say, they are "conductive"). For example, the zinc and copper strips from your kit will conduct electricity. On the other hand, paper, plastic, cloth and china are insulators. If you sharpen a pencil at both ends, and then put a wire to each end, you'll find out if graphite (the pencil lead) is conductive. Try and think of some more materials to test. Make a list of the results of this experiment, using the table printed on the next page.

CONDUCTIVE MATERIALS

NON-CONDUCTIVE MATERIALS

Diagram 18.

#11. DIRECTION ELECTRICITY TAKES IN A LIGHT BULB

Disconnect the third wire from the negative pole and put it back in your kit. Attach the wires again as you did in experiment 5 (the "light test"). Diagram 20 shows a simplified picture of this experiment. Does the bulb light up? - - It does.

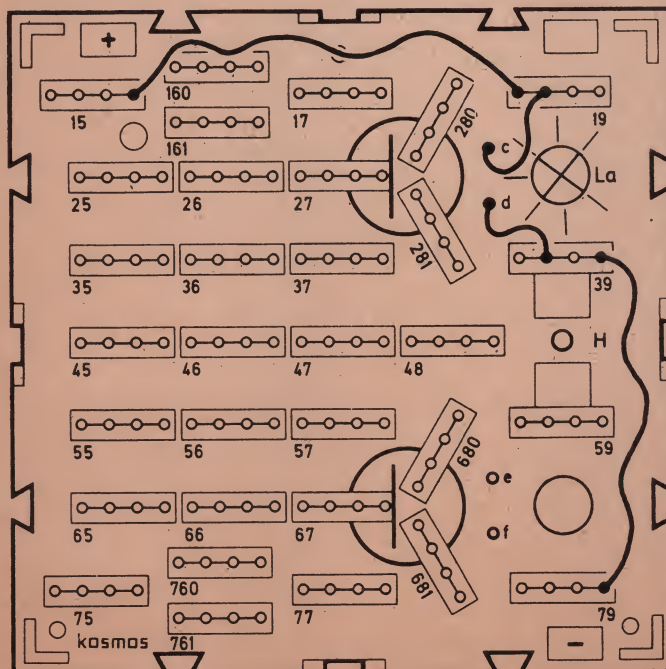


Diagram 20. Simple construction diagram with light bulb

However there is such a thing as a circuit element which allows electricity to pass only in one direction. We will learn about this later.

As you looked through this book, you probably noticed that each new circuit was introduced with a diagram like numbers 20 and 21. This important diagram will save a lot of words by showing you how to connect up your console for an experiment. We will always explain in words how a circuit works and what path the electricity takes - but as the circuits become more complicated, your careful attention to the diagram will enable you to build them, even if you find it difficult to understand exactly how they work.

17

We have drawn a circuit diagram of the circuit you now have on your console. The bulb is indicated as a circle with an x on it. When it lights up, we will occasionally indicate this by drawing little lines around it to distinguish between lit and unlit bulbs. - - That is not the usual practice, however.



Diagram 22. Circuit symbol for a bulb



Diagram 23. Circuit diagram

When the long wires lead directly to the positive and negative poles of the battery, a closed circuit is drawn (diagram 23). The positive pole is indicated by a long line with a plus sign, the negative pole by a short line with a minus sign. Near the battery poles we write in 4.5 V, since the potential of our cells totals 4.5 V. The bulb is type 3.8 V/0.07A. We have written this down beside the bulb symbol.

If the bulb ever wears out, you may replace it with a bulb only of this type. A bulb, for example, which is marked 3.5 V/0.2A would burn out some of the circuit elements in your kit, so be careful.

There are circuits which are much more complicated than the one we have just built and diagrammed. If a new part is used in one of our experiments with circuits, we will explain its diagram symbol to you in a note near the diagram in which it is first used.

One important detail: in the future we will be building circuits with wire connections from one snap clip to another. If only two wires meet in a snap clip, it is indicated as a straight line in the diagram. But if a third wire is connected to a snap clip, we indicate the intersection point with a heavy dot, and the wire that branches off is indicated as another line. The electrical path branches out in three directions at this point, since all three wires make contact.

A cross with a heavy dot in the middle indicates that at this point four wires make contact in one clip. The electrical flow in this case has four possible routes. However if

the point of intersection, symbolized by the heavy dot, is missing, we can assume that two unconnected pathways are being indicated. In this case the electrical flow must continue to move in a straight line and is unaffected by the intersection. Diagram 25 shows a circuit where wires cross in such a way without passing the current on to one another.



Diagram 24. Circuit symbols for different connections and intersections



Diagram 25. Circuit diagram

It's also important to know that in the circuit diagram, used by technicians, the wires run as directly as possible from one point to another. Therefore the arrangement of the actual circuit and of the circuit diagram can differ a bit, but the instruction diagram (20, 21) will show you exactly how connections are made.

That sounds complicated, but with practice you'll soon understand.

#13. MAKING WIRE BRIDGES

In plastic bags 23 and 24, you will find 20 blue wires, one set about $2\frac{1}{2}$ inches, and one set 2 inches in length. Out of these wires we will make wire bridges. Diagrams 27 and 28 show you how it's done. On one corner of your console you will find two extra grooves. After stripping insulation off the ends of a short wire, place it over the groove nearest the corner and bend the ends downward.

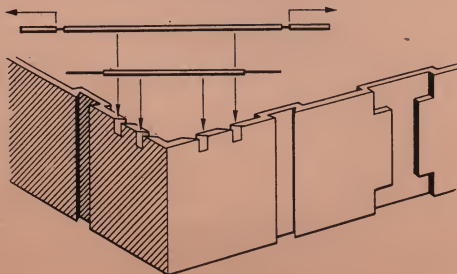


Diagram 27. Removing insulation from wires

Make sure the wire lies in the middle so that the bent ends are equally long. The long blue wires are pressed into the second groove, farther from the corner.

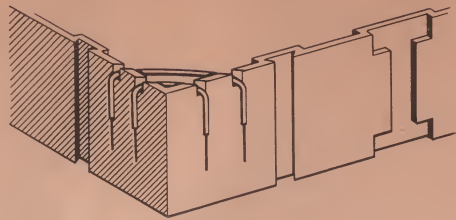


Diagram 28. Making wire bridges

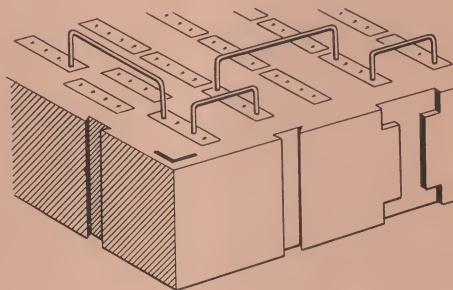
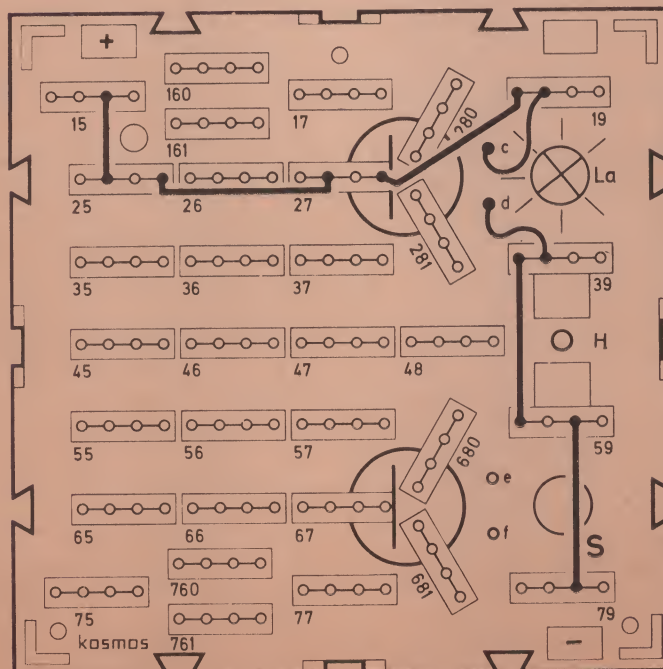


Diagram 29. Wire bridges inserted in the console

#14. CIRCUIT WITH WIRE BRIDGES



15. Diagram 30. Construction diagram with wire bridges

Now remove the long red wires from the negative and positive poles and make a circuit with the wire bridges instead, connecting them clip by clip until the bulb lights. Diagrams 30 and 31 show you a couple of ways in which you can do this.

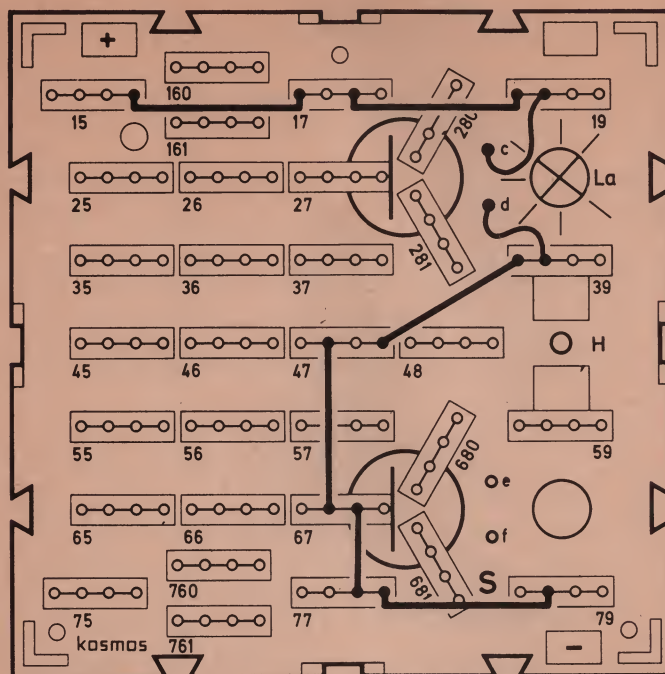


Diagram 31. Another suggestion

#15. WIRE LABYRINTH

Use all 20 wire bridges to make a circuit in which the bulb lights up. Be careful not ever to connect to one clip a wire that leads from the negative pole and a wire that leads from the positive pole. Your bulb will not light as the power flows directly from positive to negative. Your battery will be dead before you know it, because a short circuit has occurred. The best way to avoid this is always to connect the negative pole in any circuit at the very end. Then you will notice immediately if you have made a mistake, and your battery will not run down. The wire at the negative pole is the on/off switch in almost all circuits. To help you remember, it is marked with an "S" in the diagram.

#16. TRANSISTORS

For the next experiment we need a new circuit element: the transistor (15). Be careful with this part; it is very delicate.

Take it in your hand and have a good look at it. The black body looks like a little container, pressed flat on

one side. Its number is written on this flat side.

There are many transistors with different numbers; we will be using this one which the experts say belongs to the "nnp" transistor group.

Take your transistor, turn it upside down and slide it into the head of the utility tool with its legs pointing upwards. Now bend the three legs as shown in diagram 32 a.

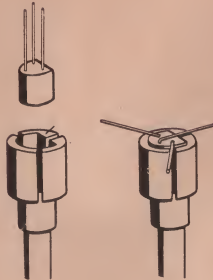


Diagram 32 a. How to bend the transistor legs

Remove the transistor from the utility tool. Turn it over and insert it into the head of the tool again, this time sliding it legs-downward into the three slots. Now press the legs down towards the shaft of the tool, as in 32 b.

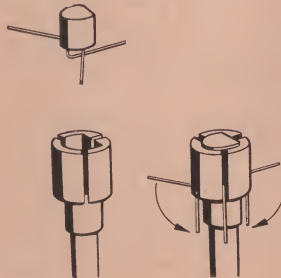


Diagram 32 b.

Set the transistor legs into the end holes of 680, 67 and 681, which are shaped like a pin wheel on your console.

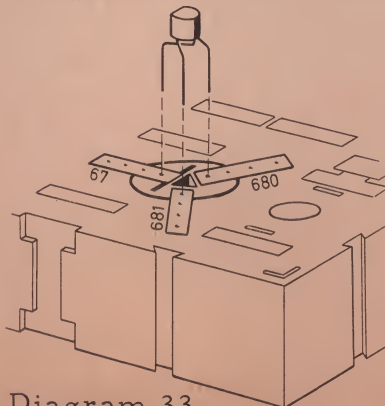


Diagram 33.

The leg which crosses over the flat end of the transistor goes into 67, the others into 680 and 681 (diagram 33) . Now we can name the legs. The leg in 67 is called the base, in 680 the collector, and in 681 the emitter. Diagram 34 shows the symbol for a transistor in a circuit diagram; B means base, C means collector and E is emitter.

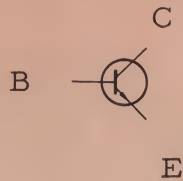


Diagram 34. Symbol for a transistor

#17. HOW THE TRANSISTOR WORKS

Now let's think about the current which the transistors allow to pass through themselves, and how the base controls its flow.

Look at diagrams 35 and 36.

The wide channel with the lock gate can be compared with the collector and emitter. The upper part is the collector, the lower part is the emitter. The two parts are divided by a lock gate. When this gate is closed, the water "collects" in the collector, and the emitter lies dry like a river bed in a dry summer.

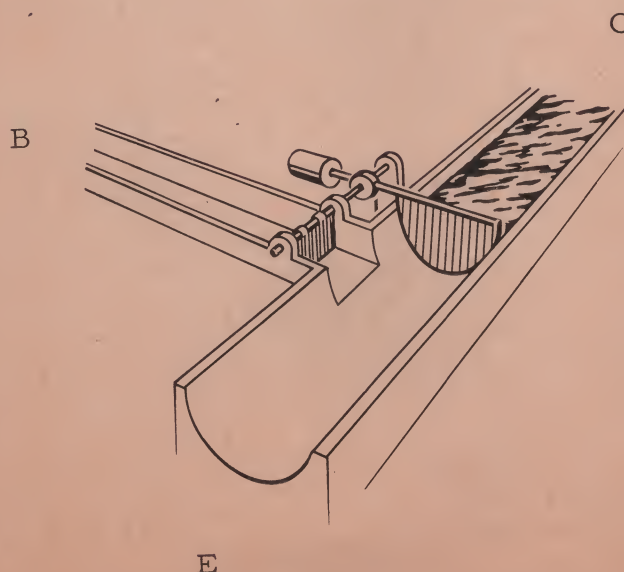


Diagram 35. Canal with lock gate

Just below the lock gate is a smaller channel, the base, which is closed by a little swinging door. This door controls the lock gate, since it is connected to it firmly. As soon as water runs through the base, the swinging door is lifted, and it raises the big lock with it. Now

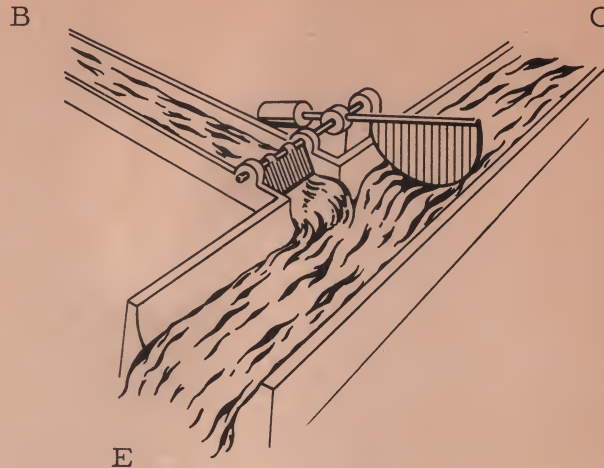


Diagram 36. Lock gate lifted

current can flow from the collector into the emitter. If the swinging door on the base opens just a bit, the lock gate in the collector isn't raised very high, either. Then the stream allowed into the emitter is small. If, however, the swinging door is raised too high, and with it the lock gate, there is a risk of overflow - - and maybe the whole system will collapse. The resistor keeps the flow into the base down, so that this will not happen.

Of course there are no lock gates or swinging doors inside our transistor. But the way the transistor works is very similar to that.

Transistors, which can be built as small as a pin point, were invented in 1948. Perhaps you have an old radio around the house, made with the large electronic tubes which determined the weight and bulk of these old machines. Your "transistor" radio is an example of improved electronics: from the traditional heavy wooden box, a radio device with transistors in the place of tubes could be reduced to fit on your wrist. Imagine how important the invention of the transistor has been for the jet and space age. Motors and electronic equipment of low weight and small proportions which can meet the limitations inherent in air transport have been made possible by this minute circuit part.

#18. BUILDING A CIRCUIT WITH A TRANSISTOR

Let's get our transistor working. First take the $3.3\text{k}\Omega$ resistor (7), (rings: orange, orange red) out of the kit. Make a bridge out of it, as you did with the long blue wire pieces. Now put the resistor into 680 and 37 where it will protect the transistor. Build the rest of the circuit as shown in diagram 37. Near 35 we apply the label "x" and near 55, a "y". You'll find both letters on your label sheet.

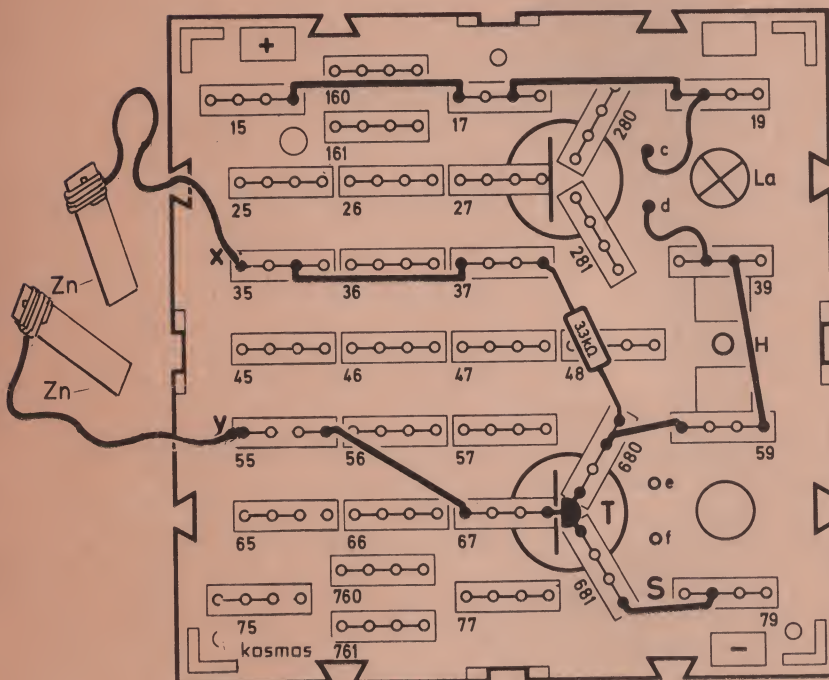


Diagram 37. Construction diagram for transistor circuit

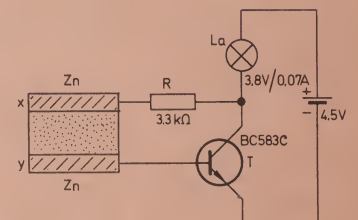


Diagram 38. Circuit diagram for transistor circuit

Once again we need the long red wires, one of which we stick into 35 (x) the other into 55(y). Now take out the zinc strips (13) and attach them to the wires as shown in diagram 39. Make sure that the bare ends of wire are pressing against the metal, and that they are held firmly in place by a few loops of wire. Otherwise you'll be annoyed when the strips of zinc keep sliding out of place.

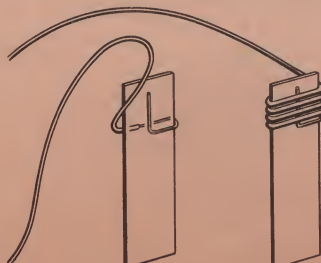


Diagram 39. Securing the zinc strips

When you touch the two zinc strips together, the bulb will light. The diagram shows how the current flows: the "swinging door" of the base has been opened enough to open the "lock gate" between collector and emitter: the current is free to flow.

#19. CONTROLLING THE BASE

Cut a strip of newspaper about 4 inches long and one inch wide. From your kitchen bring half a glass of water and a teaspoon of salt. Do this experiment on a bread board so as to keep the table from getting wet.

Put the paper strip on the bread board. In experiment 10 you learned that dry paper does not conduct. Try again and see what happens. The lamp stays off, because no current is flowing through the base channel.

What happens if you wet the paper? Dip your finger in the water and dampen the middle of the paper. Leave the ends dry.

The damp paper will act as a resistor. A resistor lets electricity pass through it, but regulates its flow.

Hold the metal strips about $1/2$ inch apart on the wet spot. The bulb will glimmer very faintly (you may have to bring the console into a dark corner to see it). The resistance level is so high, that only a little current flows into the base.

Now shake enough salt into the glass of water until it tastes a bit salty. Dampen the paper strip with the salty water and hold the zinc strips around $1/2$ inch apart on the new wet spot. The effect is amazing. The electricity flows more freely through the lessened resistance of the salt water, and the light bulb burns more brightly.

Gradually move the two metal strips apart, running them towards the dry edges of the paper. Halfway there the lamp will go out, because the resistance has become too great for electricity to pass.

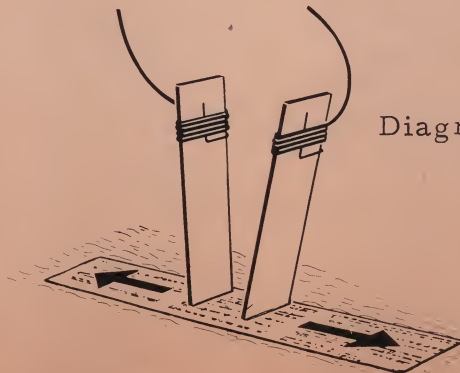


Diagram 40. Slowly separating the zinc strips

If you shake a lot of salt on the paper and wet it completely, the resistance will be so much less that the bulb will burn evenly, regardless of how far you separate the metal strips.

#20. THE RESISTOR

It's not practical to play games with water every time you want to control the current in the base. Moreover it's hard to tell how resistant the salt and water are; the resistance value is not exact. Therefore we use resistors whose resistance values have been measured. Let's take a look at them. The measuring unit of the resistor is the "ohm", named after Georg Simon Ohm, who lived 150 years ago and who made some important discoveries in electronics. Ohm is abbreviated into the Greek letter omega - - written Ω .

Every resistor has colored rings, and each color indicates a number. In table 42 you can see what number is indicated by each color. Above that in diagram 41 you can see the diagram symbol for a resistor. For our experiment we need three transistors with the values 680Ω ; $22k\Omega$ and $68k\Omega$ (nos. 8, 6, and 5 in your kit.) The small k is the abbreviation for kilo - - which means 1000. So 22k means 22,000, and 68k means 68,000.

	1st Ring 1st Number	2nd Ring 2nd Number	3rd Ring Number of 0's
0	black	black	black
1	brown	brown	brown
2	red	red	red
3	orange	orange	orange
4	yellow	yellow	yellow
5	green	green	green
6	blue	blue	blue
7	violet	violet	violet
8	grey	grey	grey
9	white	white	white

Diagram 42. Table of resistor colours

First take the 680Ω resistor. The first ring is blue. Look at the table of colors (diagram 42) , and we see that the color blue means 6. The next ring is grey and means 8. The third ring will tell you how many zeros

follow the first two numbers. On our resistor we find brown in the third ring, which means - = 1 zero. Now write out the numbers one after another, and the result is the number 680. So we know the resistor has a value of $680\ \Omega$. You can find out the values of all the other resistors with the help of the color chart. As soon as you have found out the resistor's value, you can take out the right label from your label sheet and wind it around one of the wire ends.

Remember that an orange color in the third ring means three zeros or in other words, a kilo. The resistor with two red rings and one orange colored ring has a value of $22,000\ \Omega = 22\text{k}\ \Omega$. The more "ohms" a resistor has, the higher its resistance value, and the harder it is for electricity to get through it.

You may have noticed a fourth ring on your resistors. This last ring is always either silver or gold, and is an indication of quality. It can be disregarded when you calculate the value of the resistor.

#21. TESTING THE RESISTOR

Now put the long red wires with the zinc strips aside and stick the $680\ \Omega$ resistor into the clips between x and y. The light burns brightly. So we know a lot of electricity is flowing through the transistor (diagrams 43 and 44).

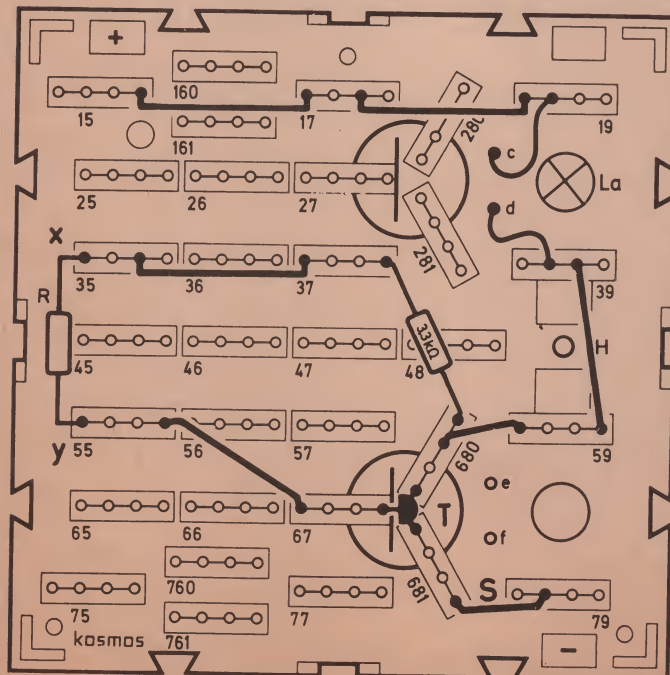


Diagram 43. Construction diagram for resistor tester

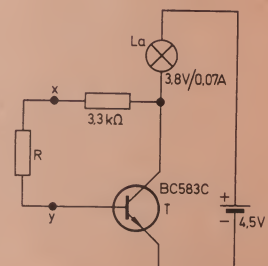


Diagram 44. Requals $680\ \text{ohms}$, $22\text{k}\ \text{ohms}$, or $68\text{k}\ \text{ohms}$.

Substitute the $680\ \Omega$ resistor with the $22k\ \Omega$ resistor and you will find it lets much less current into the base. As a result the transistor allows much less current through--the bulb burns more weakly.

When you replace the $22k\ \Omega$ resistor with the $68k\ \Omega$ resistor, you'll be lucky if the bulb even glimmers. Darken your room and you may see a small bright point.

You can see that it's much simpler to work with resistors than to regulate the power with paper and water. Circuit diagrams often indicate the resistor with the letter R. In diagram 44 we indicate the resistance values of the resistors used in the test.

#22. TRANSISTOR IN DANGER

The transistor is very sensitive -- that's why we protect it with resistors. If you ever make a mistake while building a circuit, and overload the transistor, it will become so hot that you won't be able to touch it. So check every once in a while with your finger -- and if you notice that it's getting hot, break the circuit immediately by disconnecting the wire from the negative--even before you begin to look for the mistake.

#23. POLLUTION TEST

Build circuit 45 on your console. With it we will test whether there is such a thing as water that does not conduct.

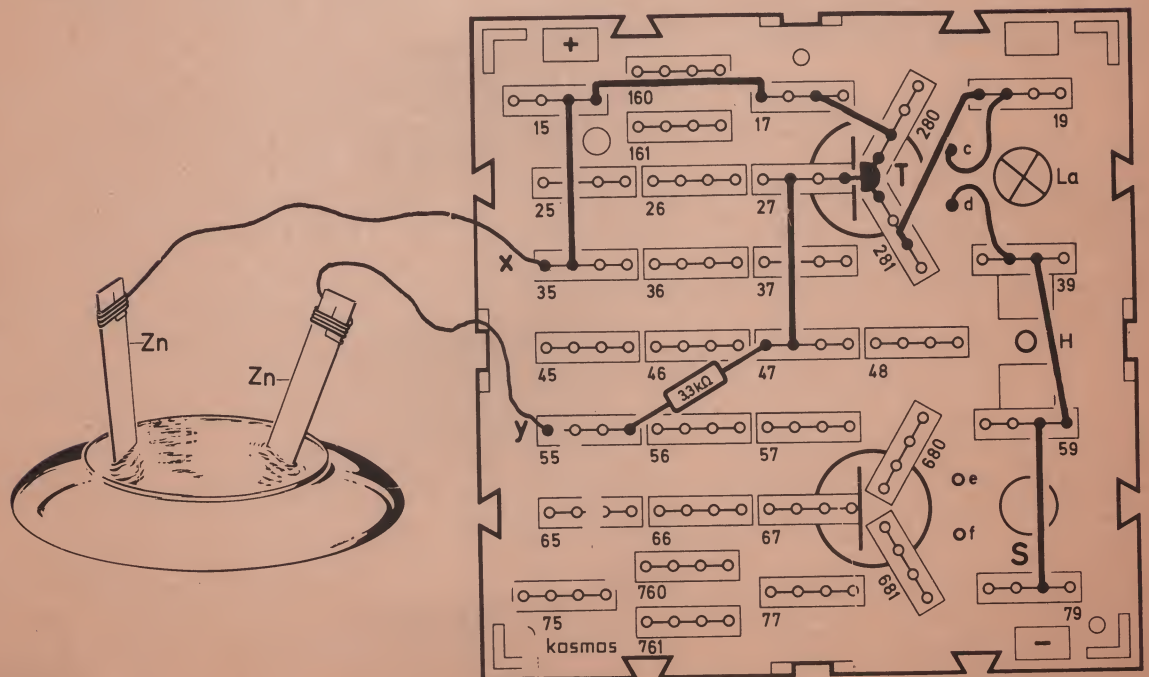


Diagram 45. Construction diagram for pollution tester

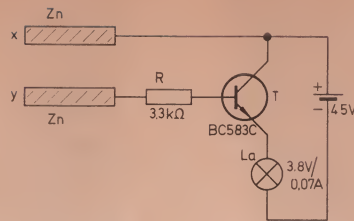


Diagram 46. Circuit diagram of a pollution tester

As you can see by looking at diagram 46, the bulb and battery have changed position in the circuit: before when we checked the resistors, the bulb was situated at the collector and the negative pole of the battery at the emitter. Now in the pollution test the bulb is connected with the emitter and the positive pole of the battery with the collector. The fact is, one can change the order of circuit elements that lie next to one another in a power line, as long as no line branches off between one of these elements. By turning things around this way we want to make things easier for you when you change the circuit into a rain detector later. That's why we moved the transistor up next to the bulb.

We have already seen that water's ability to conduct, which depends on a chemical process, increases when salt is added to it. Now we are looking at this in a new way: we want to test water to see how pure it is. Amazingly enough, water with no chemical content - - such as salts, acids, lye or chlorine - - doesn't conduct electricity at all.

For our experiments we need a saucer and a spoon. Fill the saucer with tap water and place the zinc strips into it, making sure they do not touch. The bulb indicates right away: tap water is not pure. It conducts, and electricity is able to run through the base of the transistor.

What about distilled water? You can buy it in drug stores - - because of its purity, it is used for chemical experiments, and also to add to car batteries. Perhaps you have a bottle of it lying around somewhere at home and you can use it for your experiment.

There really should be nothing in distilled water, but sometimes it's not completely pure; in that case, our pollution detector will let us know. Of course you must be sure to clean your zinc strips before every experiment - - otherwise the deposit that is left on the metal from the last experiment will give you a false result. If you hold the zinc strips in the distilled water and the bulb doesn't light, the water is non-conductive and pure.

Rainwater should be pure. If it's raining, try and catch some rain as it falls by setting the saucer on your doorstep, balcony or in your garden. When you have enough, test it for impurities. Now you will find out how clean the air is - - if the bulb lights, the dirt in the air has polluted the rainwater.

You should have your best luck with the frost in your freezer. Don't take the ice cubes, which are made of frozen tap water. As a container use the underside of the saucer. Scrape some of the frost off the freezer wall with a spoon. Let it thaw out, then wipe the zinc strips clean and put them into the water. If you were careful, the bulb will not burn, because no power can flow through the pure water into the transistor base.



Diagram 46a. Scraping frost from a freezer wall

Do you have any soft drinks on hand? Pour either a drop of soft drink or a bit of salt into the pure water. As soon as a trace of impurity enters it, the bulb lights up.

So you see: the less impurity there is in water, the less it conducts electricity.

#24. BATTERY POLES IN TRANSISTOR CIRCUITS

It's important to remember that in transistor circuits the battery poles must be connected properly to the transistors. If e.m.f. is applied against the wrong side of the "swinging door" in the base canal, the lock gate won't open.

It won't be hard for you to simplify the construction of the pollution tester as shown in diagram 47. Then the relationship between battery poles and transistor will become clearer.

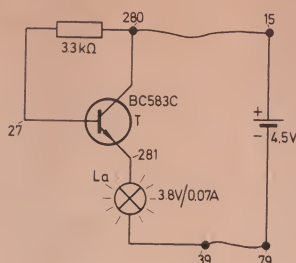


Diagram 47. Circuit diagram showing position of battery poles in a transistor circuit

The transistor remains in 27, 280 and 281 - - but all the blue wire bridges are removed. The bulb connection wire from "c" is attached to the emitter (clip 281), the lamp wire from "d" is connected to 39. The 3.3 kΩ resistor is placed between base and collector, - - between 27 and 280. A long wire connects 39 with the negative pole 79, another long wire connects the collector 280 with the positive pole 15. Now the bulb lights.

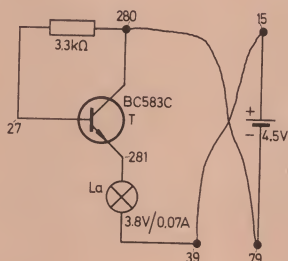


Diagram 48. Battery poles reversed

Now switch the long wires, so that one leads from 39 to the plus pole, and the other from the collector 280 to the minus pole. Since the current cannot flow, the bulb does not light.

#25. RAIN DETECTOR

Most people follow the weather report on radio and T.V. with great interest, because everyone wants to know what the weather will be like tomorrow. - - But you can't always depend on the weather report. Sometimes it rains when bright sunny skies were predicted.

You won't be surprised by the rain anymore if you set your rain detector out on the window sill. The next morning when you open your eyes, you won't even have to get out of bed to tell whether it's raining or not.

Build the rain detector as shown in diagram 49. Now the zinc strips, half covered with absorbent paper, will be your rain antennas.

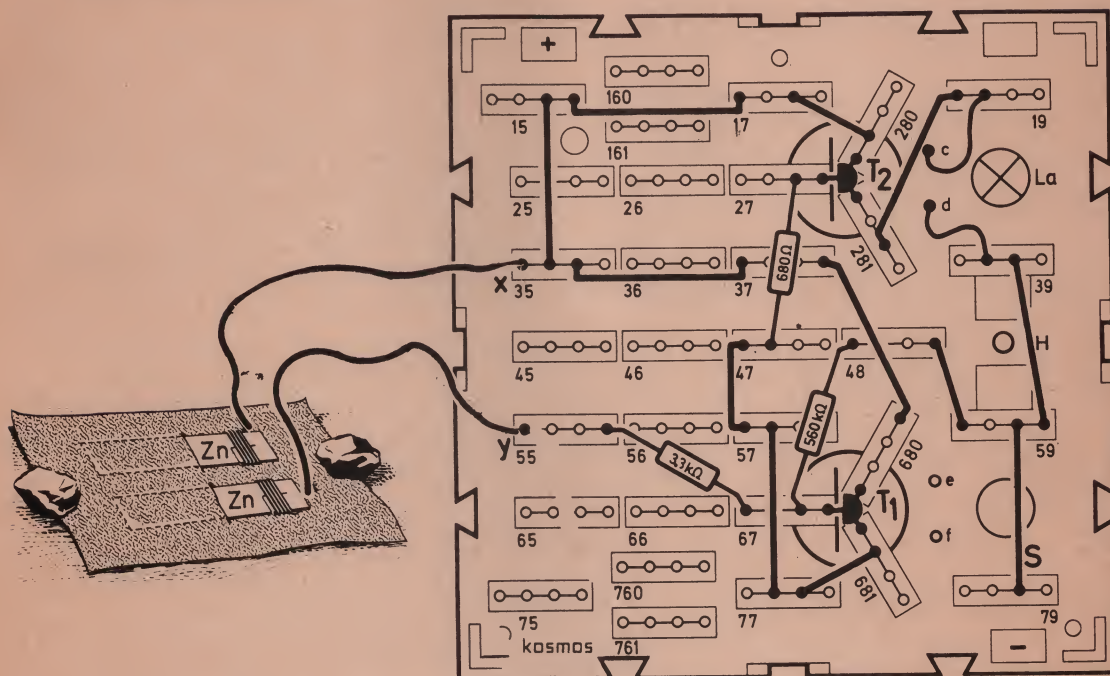


Diagram 49. Construction diagram for rain detector

You'll be using two transistors for the first time. Bend the second transistor into shape with your utility tool as you did with the first one and set it in 67 (base) 680 (collector) and 681 (emitter). From the label sheet take the label T₁, and apply it near this transistor; the other one receives the label T₂. In the future it will be easier to speak of T₁ and T₂ when we have to talk about the transistors.

Because rainwater doesn't conduct as well as tap water, the electricity that passes through the zinc rain antennas is not enough to open the large "lock gate" of the transistor so that current from the emitter can make the bulb light. In this case only a second transistor can help. Our transistors have emitter currents which are five hundred times stronger than their base currents.

If we use the emitter current of T₁ as the base current of T₂ (The bulb transistor), the base current of T₁, which comes through weakly from the rain antennas only has to

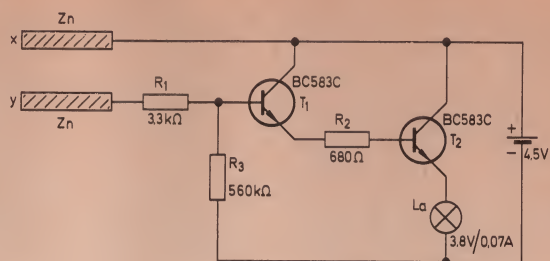


Diagram 50. Circuit diagram for rain detector

make up $1/500$ of the base current of the bulb transistor.
 - - So the bulb will light up, brightly. The weak current from the rain antennas is now sufficient. The rain opens up T_1 and T_1 opens up T_2 (circuit diagram 50). The resistors R_1 ($3.3k\Omega$) and R_2 (680Ω) will control the current flow in the base properly.

When you are ready to use your rain detector, set it on the window sill and put the zinc rain antennas outside on the ledge. Put the antennas on a wooden or plastic tray, since window ledges are usually dirty and sometimes made of metal. This would ruin the accurate work of your rain detector.

If the wind is blowing very strongly, you must secure the antennas with a couple of stones - - but don't let the stones touch the zinc strips themselves.

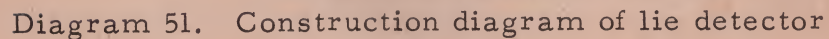
As a rule we like the sun - - but now let's hope for a good rain shower, so that our rain detector has a chance to work.

#26. LIE DETECTOR

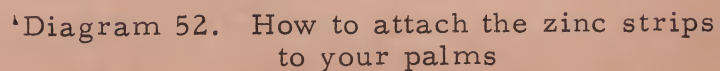
You've probably already noticed how you suddenly begin to perspire when someone tries to force you to reveal a secret. The palms of your hands become damp, and your heart starts to beat more quickly.

Everyone reacts like that when they are afraid they might betray something they want to keep to themselves. Scientists noticed this and developed a device which measured the moisture in the palms. Because the device was used primarily in police investigations at first, it was called a lie detector.

Build a lie detector by following circuit diagram 51. With it, you can test brothers, sisters and friends. Attach the zinc strips to the hands of your partner with adhesive tape, and then ask him questions. If there's one among



If your friend takes the test as a joke, he won't perspire, and the lie detector won't work. Then you can play a little trick on him. Secretly wet your fingers and "check" (touch both zinc strips at the same time) to see if the lie detector is attached properly to his hand; then it's a question of whether he pulls the wool over your eyes by lying--or if you pull the wool over his eyes by tricking him!



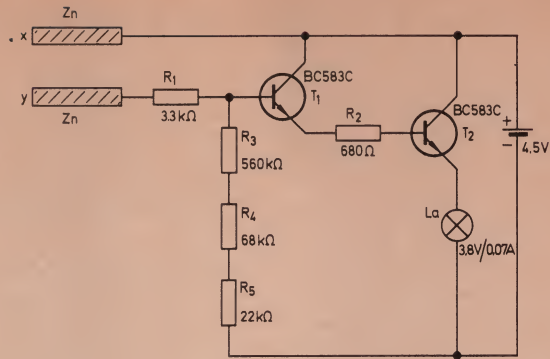


Diagram 53. Circuit diagram for lie detector

Compare the circuit diagram of the rain detector with that of the lie detector (diagram 53). In principle the two circuits work the same, and at first glance their only difference is that R_4 and R_5 are linked to R_3 . R_4 and R_5 increase the total resistance value of R_3 . What does R_3 actually do? We can explain that using once again the example of the "lock gate". R_3 stands for the weight of the big lock gate. As long as no current flows through the base and opens the swinging door, the big lock gate is held down by its own weight. As long as it's closed, its weight isn't important. But as soon as current flows through the base channel, the weight of the lock gate makes a big difference. If it doesn't weigh too much, a weak base current is enough to open the gate. But if it's very heavy, the base current has to be stronger to open it. If you lessen the weight of the lock gate - - for example, by balancing a weight against it, - - you can influence the sensitivity of the system to a certain extent.

Looking at it from an electronic point of view: if you increase R_3 (connecting R_4 and R_5 does this), it has the same effect as if you increased the weight of a balance against the lock gate, and this makes the lock gate easier to lift. The system becomes more sensitive - - that is, a smaller electrical signal will pass through the transistor and turn on the bulb.

We know that the lie detector works when the perspiration on the palms increases. Then the resistance between the hand surface and the zinc strips lessens, the base current becomes stronger and the bulb burns more brightly. Because we connected R_4 and R_5 with R_3 , the sensitivity of the system is increased to the point where the lamp glimmers a bit even when the hands are rather dry. Since the contact resistance in people's hands varies, we may have to simulate perspiration with ordinary water.

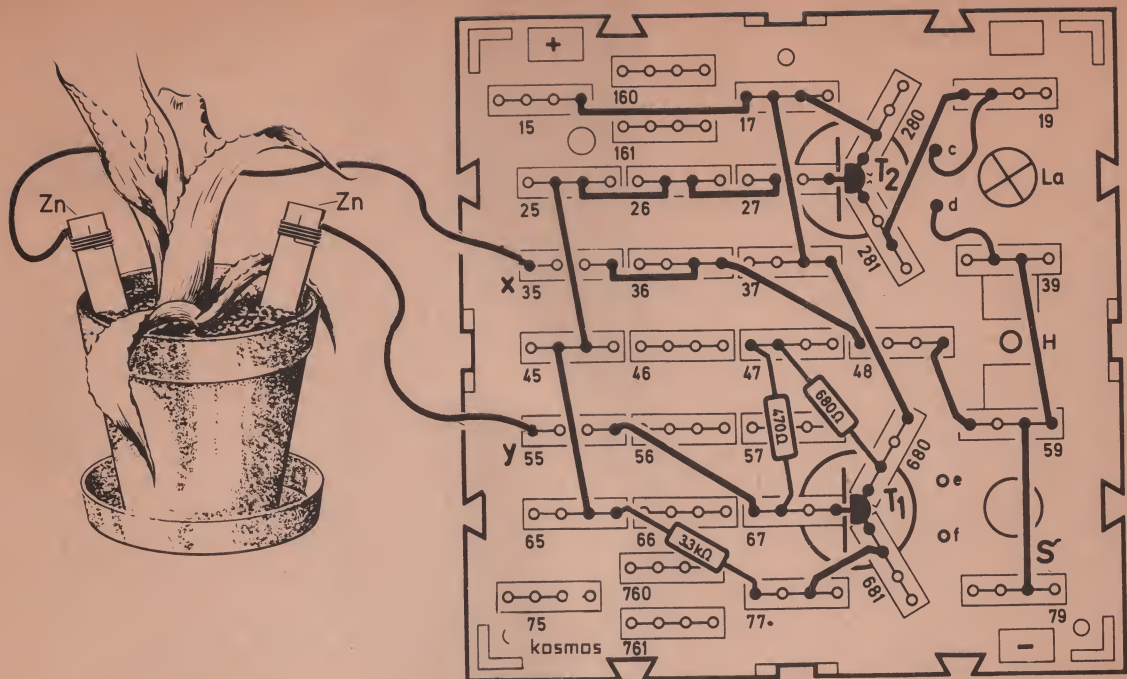


Diagram 54. Construction diagram of electronic gardener

#27. ELECTRONIC GARDENER

In heated rooms the air is often quite dry. Water in flower vases evaporates quite quickly, and humidifiers in central heaters must be adjusted often.

Our potted plants often have problems with dry air, because the soil in the pot dries out quickly. Our electrical gardener will help us to check the soil easily.

Build circuit 54. The bulb burns when the zinc strips are not touching one another, and goes out the moment they are held together. Unlike all the other circuits which we have built up to now, the bulb burns when the zinc strips don't make contact.

Now get a potted plant and check to see if it has to be watered. Push the zinc strips into the soil not too near the plant, so as not to injure its delicate roots. If the lamp bulb lights, it's high time to water the plant. As you do it, watch the bulb. The more water absorbed into the earth, the weaker it burns. As soon as the earth is completely soaked, the zinc strips make electrical contact through the conducting water, and the bulb extinguishes.

Leave the metal strips in the pot, so that you can check whether the plant needs watering again tomorrow.

Break the circuit at the negative pole until the next time you take a measurement, since the circuit absorbs power even when the bulb doesn't light up. This power is called "quiescent" current, and it makes up only 1/20 of the power needed to burn the bulb - - but even this slow drain will eventually discharge the battery.

This circuit reverses the circuit we used for the lie detector, since, unlike the last circuit, this one does not allow the lamp to burn when the zinc strips are touched.

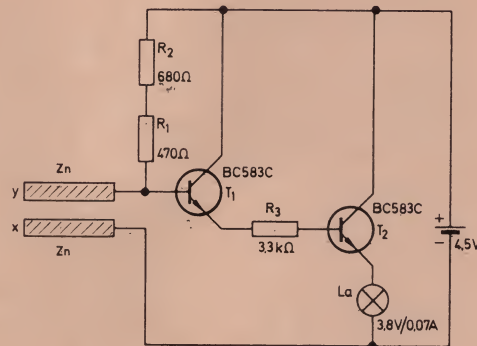


Diagram 55. Circuit diagram for electronic gardener

Compare the circuits. In the lie detector the resistors lie between the base of T_1 and the negative pole, and in the electronic gardener, they lie between the base of T_1 and the positive pole. So in the electronic gardener, the base of T_1 is not held open via a water bridge, but rather via the resistors R_1 and R_2 .

If the zinc strips don't make contact, the current that comes from R_1 and R_2 has no choice: it has to go through the base channel to the emitter of T_1 and T_2 . The two transistors open up and the lamp bulb burns brightly.

If the plant soil is damp, it conducts the current between the two zinc strips. The current which was going through the resistors before now has two possible paths. Because electricity always takes the easiest path, more and more current flows through the zinc as moisture increases. We can see that as the bulb slowly extinguishes. Finally hardly any electricity at all flows along the base channel of T_1 , and the bulb extinguishes.

You've probably noticed that the resistors used between the transistors in the gardening device are much higher

in value than those in the lie detector. The base of T_1 is much less protected in the gardening device than in the lie detector - - that's why the emitter of T_1 must be tightly controlled. The resistor at the emitter of T_1 acts at the same time as the protecting resistor for the base of T_2 . Because of its double role it must have a correspondingly high value.

You can check all the potted plants in your home for moisture with this electronic gardener.

#28. THE QUIZ CLOCK

You can organize a quiz game with your friends and use this quiz clock to keep time. Two couples play against one another. You pose a question to which there are as many answers as possible - - for example: how many kinds of ball games can you name? - - One couple goes first, one person calling one name, the other the next one, back and forth as fast as they can. The second couple has a chance at the same question later.

The group that names the most ball games wins.

One of your guests will have to watch the quiz clock and say when the time agreed upon is up. Two other friends make up a jury who count the answers.

There are many such games, and you can use your imagination to figure some out. Once you have built the circuit you'll quickly see how the quiz clock works. When you push the control key, the bulb goes out, and after five or ten seconds it comes on again. In your games you'll want to press it two or three times to allow sufficient time for the answers.

To build your circuit you need two new circuit elements (diagram 56 and 57): the control key 19 and the electrolytic capacitor $10\mu F(11)$. F means Farad,



Diagram 56. Control key (small black triangle pointing upward means that the key springs up when released).

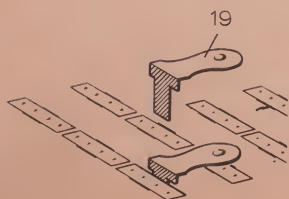


Diagram 57. Inserting the control key

named after the English physicist Michael Faraday who lived in the last century. μ is read as "micro" and it means, when it is placed before a measurement, one millionth part of that measurement. Our electrolytic capacitor (E.C.) has a value of 10 microfarads. From now on when we talk about the electrolytic capacitor, we will say "E.C."



Diagram 58. Symbol for an electrolytic capacitor

Slide the control key into the slit on the side of snap clip 75 so that its head rests above clip 65 (diagram 58), and insert the E.C. into 75 and 35. On one end of the E.C. you will notice a groove, near which a plus sign is indicated. It is important to attach the positive end of the E.C. to the proper clip (in this case 55, as shown in the diagram): if you attach it the wrong way around, your circuit may not work, and E.C.s break down slowly when they are not connected properly. The circuit diagram always shows in which direction it should be placed.

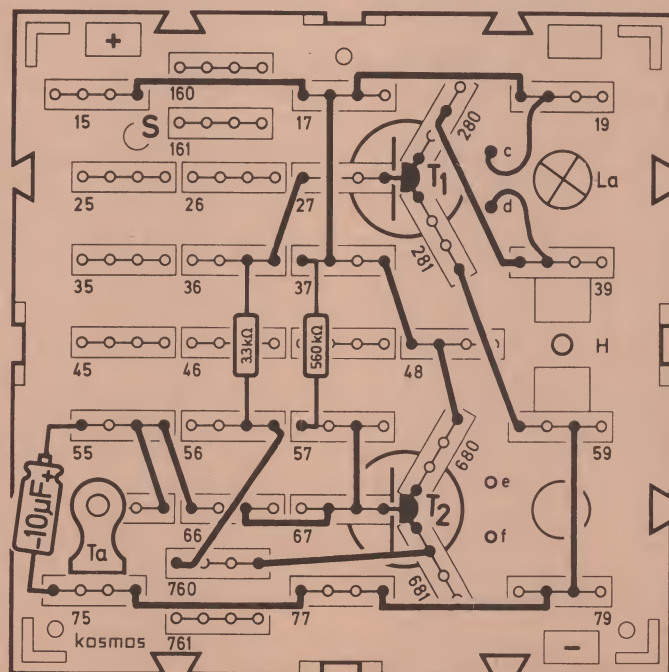


Diagram 60. Construction diagram of quiz clock

Now build circuit 60. The bulb will light up, if you did everything correctly. Press the key down, release it and watch the bulb. When you press the key, the bulb goes out and goes back on after five to ten seconds.

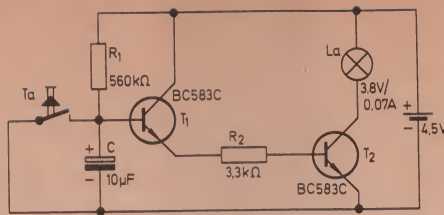


Diagram 61. Circuit diagram for quiz clock

How it works

Look at circuit diagram 61. The current travels through R_1 and opens the base of T_1 . As soon as you press the key, the current flows past the transistor to the negative pole of the battery. If you release the key, the power doesn't flow directly into the base of the transistor again; instead, it fills up the E.C. We say the E.C. is "charging". The E.C. works like a tub with an overflow drain - - and the overflow drain is the base channel of the transistor (diagram 62) .

Only when the E.C. is full enough does the current flow again into the base, open up T_1 and then T_2 . E.C.s store electricity - - like all capacitors.

You can easily recognize what an E.C. does in a circuit by removing it from the console. When you release the key after pressing it, the light bulb turns on immediately.

The bulb is situated between the positive pole and the collector of T_2 because we want it to go on as suddenly as possible.

And now - have lots of fun with the quiz game!

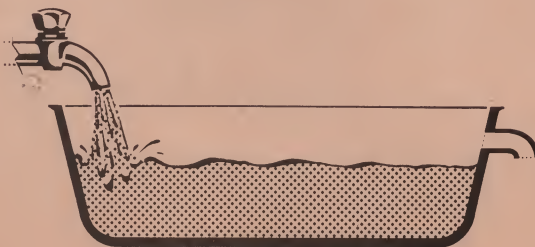


Diagram 62. Tub with overflow drain

#29. AUTOMATIC LIGHT SWITCH

Perhaps you have seen lights in a public place which, when turned on, switch themselves off automatically a few minutes later. All one has to do is push the switch, turn the light on and then forget about it - it goes out on its own. This kind of light is good in a hall or stairway.

Construct circuit 63, with which you could illuminate a two-storey doll's house or the cellar steps of a little store. Of course the bulb will light up only for a few seconds, but for your purposes that's enough.

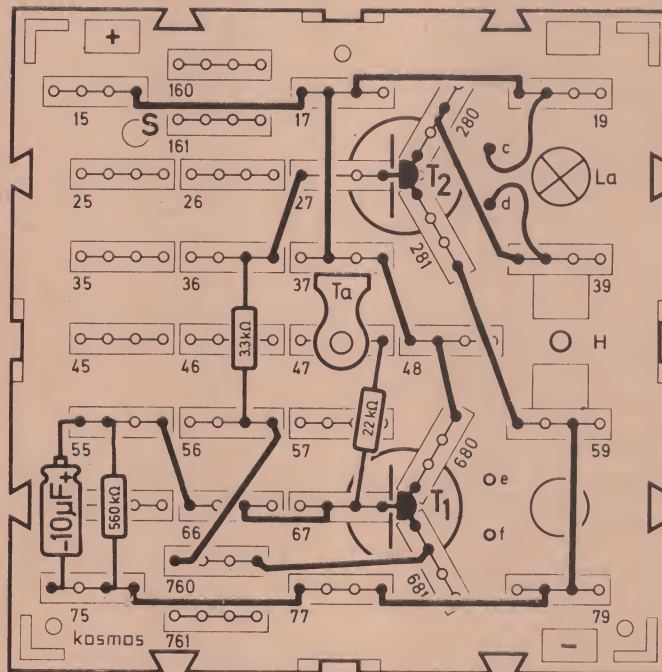


Diagram 63. Construction diagram of automatic light switch

You can also put this circuit at your bedside, and if you wake up at night, you can push the control key to see what time it is on your clock.

It's practical for you if you share your room with somebody, since the tiny light won't disturb anybody. Don't forget though, that the "quiescent" current will eventually empty the batteries, even when the light isn't on.

Were you ever in a dark room, where film and photos were prepared? In order to prevent light from shining on photo paper too long, they use an automatic light



Diagram 64. Dark room.

switch which works electronically like our circuit does. Even the length of time that the light stays on is the same as our bulb's.

How it works

Our explanations will become more complicated now, but try to follow what we say by looking at the real circuit diagram 65. This circuit is similar to the quiz clock: in both, the E.C. is marked with a "C". The only difference is that the control key of the quiz clock was situated at the negative pole, but in this circuit it's at the positive pole of the battery. In this automatic light the lamp is off as long as the key is not pressed. If you push the key, the electricity which was headed for the base of T_1 travels past the transistor for a fraction of a second, and charges the E.C. Then it opens up T_1 and finally T_2 . The bulb lights up.

When you release the key, the bulb doesn't go out immediately, because a part of the electricity which was stored in the E.C. flows through the base of T_1 and keeps it open.

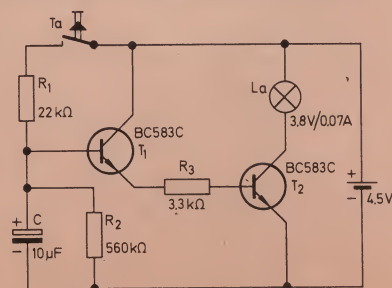


Diagram 65. Circuit diagram for automatic light

We compared the E.C. to a tub and the base to its overflow drain. As soon as the water level in the tub sinks below the drain, no more water can flow out. That explains why only a part of the current that is stored in the E.C. flows on to the base. But nevertheless the base of T₁ needs really only a little current, and it would be a long time before the bulb went out if there were no other route along which the electricity could be discharged. Therefore the resistor R₂ is connected parallel to the E.C. With it, the time in which electricity is discharged becomes shorter since it connects the positive and negative ends of the E.C.

That means the bulb will remain on for a shorter time period.

In the circuit, R₂ is a 560 k Ω resistor, which allows the bulb to burn for 5 - 7 seconds. The smaller the resistor, the shorter the time the bulb will operate.

If you want to check to see how long the bulb stays on, if the power from the E.C. discharges only through the base channel, all you have to do is to remove R₂ from the circuit. Then it takes nearly a minute before the bulb extinguishes.

#30. SPY DETECTOR

If you want to check whether anyone has opened your cupboard or drawer, you can use your spy detector. All you need to do is to secure the zinc strips so that they come into contact with one another when the drawer or door is opened.



Diagram 66. Spy in the closet

In order to prepare the spy detector for use, push the control key. If the zinc strips touch, the bulb lights up. Even when the zinc strips are moved apart or touch one another again the lamp doesn't go out. Only when you press the key again does the bulb go completely out.

You'll be even more clever if you take the bridge between 45 and 65 out of the circuit, after you pressed the key to put it in working order. Then no one else can extinguish the bulb by pressing the key.

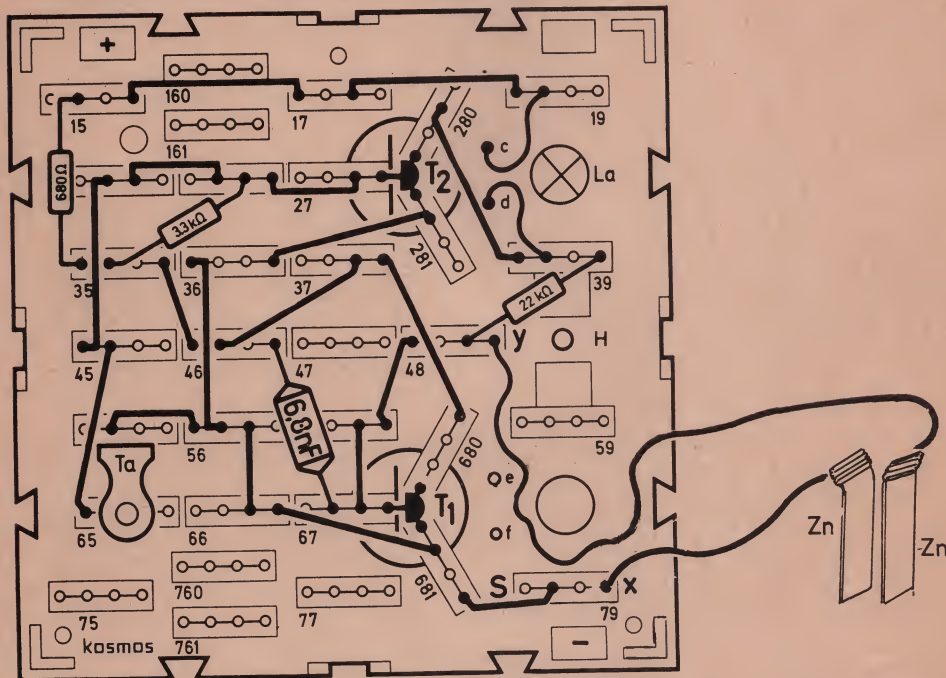


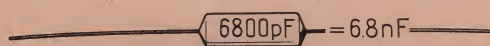
Diagram 67. Construction diagram of spy detector

Build circuit 67. Again you need a new circuit element - this time the 6.8 nF capacitor (10) (diagram 68 and 69) . nF means nanofarad. A capacitor with 1 nF has only 1/1000 of the capacity of a 1 μ F capacitor. In other words, the 10 microfarad E.C. has a capacity of 10,000 nanofarads.

In this circuit stick x to clip 79, y to clip 48. The long wires with the zinc strips are attached to 48 and 79.



Diagram 68. Circuit symbol for E.C.



69. Capacitor

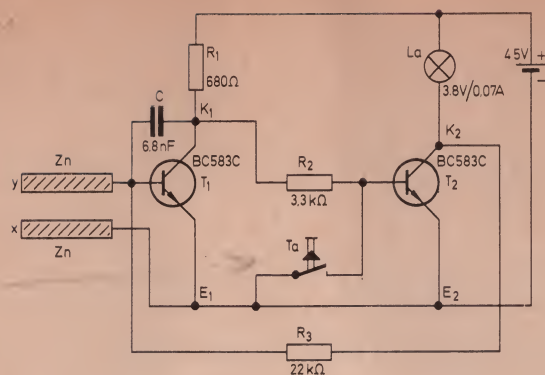


Diagram 70. Circuit diagram for spy detector

How it works

Look at diagram 70. As you constructed this circuit you must have noticed that it is more complicated than others you have built up to now. On the diagram, the collector streams of T_1 and T_2 are indicated as K_1 and K_2 , the emitter streams as E_1 and E_2 , and the E.C. as C. (This system will continue throughout the following diagrams.)

While in other cases T_1 was responsible for opening T_2 , the transistors in this circuit play independent roles. One of them is always closed while the other is open. As long as T_1 is open, T_2 is closed, and as long as T_2 conducts electricity, T_1 is closed. If the base of the operating transistor is connected to the negative pole by pushing the key or touching the zinc strips together (each of these operations affects one of the transistors) the base channel of the affected transistor is closed. Then the other transistor takes over and begins to conduct. The experts call it a "bistable multivibrator", because both systems that pass through the transistors are so stable, they don't switch over unless interfered with.

T_1 and T_2 work like electronic switches. If one transistor is opened up by current through the base channel, collector and emitter are connected up, and current from K flows over E to the negative pole. If the transistor is closed, K and E are not connected.

If T_1 is closed, its collector stream is connected via R_1 to the positive pole; if T_2 is closed, its collector K_2 is connected via La to the positive pole.

By pushing the key, current in the base stream of T_2 is forced to move to the negative pole and T_2 closes. The bulb goes out. K_2 has a connection via the unlit bulb to the positive pole.

Via R_1 and R_3 , the electricity flows to the base of T_1 and opens it. This base current is so weak, that L_a doesn't light. Because T_1 is open, C_1 is connected via E_1 to the negative pole. Therefore the base of T_2 stays closed when the key is released.

Now if the zinc strips touch, the current flow of the base in T_1 is directed to the negative pole and the transistor is closed. So the connection between K_1 and E_1 is broken, and current flows from the positive pole via R_1 and R_2 to the base of T_2 . Since the base channel has current, T_2 opens up and the bulb lights. Because of the connection between K_2 and E_2 , the current from the base of T_1 flows to the negative pole via R_3 , K_2 and E_2 . Therefore T_1 is closed, even when the zinc strips don't touch, until someone pushes the key.

The capacitor (marked "C") makes sure that one transistor system doesn't switch over to another on its own.

This circuit is quite complicated. Read it through again and follow each step in the circuit diagram. Then you'll find it easier to understand the circuits we'll be building in the following experiments.

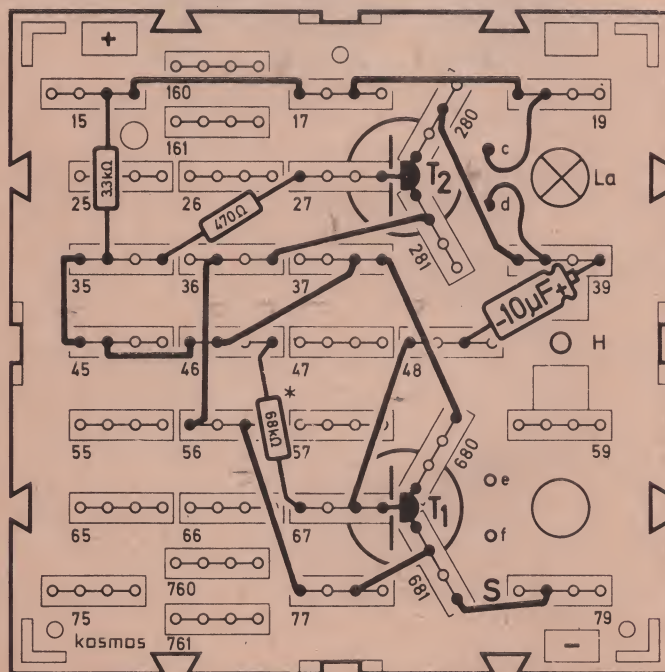


Diagram 71. Construction diagram of lighthouse light

#31. SIGNAL LIGHT

Ships at sea are able to keep course by watching the stars and also by using measuring devices that show them the right way when it's cloudy, stormy and rainy. If they mistakenly come too near the coast, they are warned away



72. Light house

by lighthouses, buoys and signal ships, which help them to avoid reefs and sandbanks. Lighthouses send long rays of light into the darkness.

How does one distinguish between the different lighthouses? If they all sent out the same signal, it could be dangerous for homecoming ships, since the pilot might find it hard to tell the difference between Boston, Rhode Island or New York. Then the ship might leave its course and stray into shallow water. For that reason every lighthouse sends its signals at different time intervals. Every steersman knows the code of signals and can tell where he is when he sees one.

Build circuit 71, first without R_1 (resistor $68k\Omega$ between 46 and 67). Remember to place your E.C. with the positive sign in the right direction. The bulb will light, if you do everything right. - - This will teach you something important, because even the light which the lighthouse beams out burns, in a sense, all the time. The constant stream of light is made into a light signal when it is interrupted at regular intervals.

In our circuit R_1 controls the coding. Now attach the $68k\Omega$ resistor to 46 and 67 and watch the bulb. After about two seconds it goes out and then lights up again. One after another you can try the resistors $68k\Omega$, 560Ω and 680Ω in the R_1 position. $68k\Omega$ gives a 2 second signal, $560k\Omega$ a quarter minute, and 680Ω a flickering on-off effect. Try the $22k\Omega$ to see what code signal it has.

With the spy detector we had a circuit with a bistable multivibrator. Only when you touched the control key did the power switch over from one transistor to the other. In the case of the signal light the circuit switches from one system to the other on its own. For that reason the expert calls it an "unstable multivibrator". So, we don't need the control key and the contacts between x and y for the signal light.

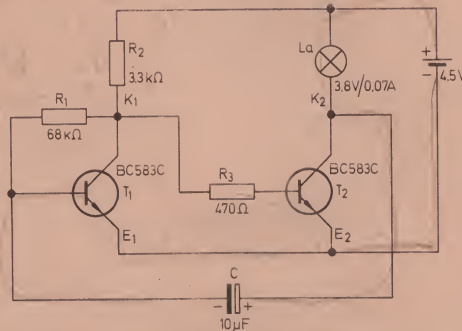


Diagram 73. Circuit diagram for light house
 R_1 - $68k\Omega$ or $560k\Omega$ or 680Ω

How it works

Look at diagram 73. The bulb goes off when T_2 is closed. The E.C. is connected to the bulb with its positive pole towards the positive pole of the battery, and its negative pole connected to the base-emitter stream and the battery's negative pole. The E.C. is charged, therefore, by the lamp current. Its stored current is enough to hold the base of T_1 open, but is not enough to light the lamp. While the E.C. is charging, the current does not flow to the base of T_1 and T_1 begins to close. So the "lock gate" between K_1 and E_1 closes, and the current, which otherwise would take this route, now flows through R_3 to the base of T_2 and opens T_2 . The lamp L_a goes on.

The length of time that the bulb stays off depends, therefore, on how long it takes until the E.C. is charged. That happens fast, so the period of darkness is short.

Because K_2 is now connected with E_2 , the positive pole of C sends current via K_2 and E_2 to the negative pole of the battery. Because the negative pole of the battery is also connected to the emitter of T_1 , C lies between the emitter and base of T_1 .

Here we're using a trick which shuts T_1 for a time, but also we make sure, on the other hand, that T_1 will open up on its own; for that we use the discharging period of the E.C. For as long as C is being charged and T_1 stays closed, T_2 remains open and the bulb burns. How does this trick work?

As long as an E.C. is charged, you can look at it as a battery, because there's potential between its poles and it wants to pass on its electricity (the electricity with which it is charged). In our case the discharged current cannot flow via the base-emitter of T_1 ; for the E.C. lies with its negative pole towards the base, and its positive pole via K_2 and E_2 at the emitter of T_1 . The discharge current would not flow into the base channel but rather would have the tendency to flow out of it. The potential with which the E.C. is charged "sucks" at the base, so to speak, and this suction effect holds the base gate tightly closed.

So the E.C. must find a different way to discharge its current. This is done with the help of a weak battery current, which flows from the positive pole of the battery via R_2 and R_1 to the negative pole of the E.C. and from the positive pole of the E.C. via K_2 and E_2 to the negative pole of the battery. After this current flows awhile, the E.C. is discharged.

The greater the resistance value of R_1 and R_2 , the longer the discharge process lasts and with it the light interval.

The battery current, of course, does not stop flowing when the E.C. is discharged, but rather it flows on and then acts as current which tries to charge the E.C. backwards.

As soon as the E.C. has absorbed a bit of this charge, its suction effect on the base of T_1 stops, and current can flow from the positive battery pole via R_2 and R_1 into the base channel of T_1 and open the transistor.

As soon as K_1 and E_1 are connected, the current that until now flowed via R_3 into the base of T_2 is diverted via E_1 to the negative pole of the battery. Therefore no current flows via R_3 any more, the base of T_2 is closed

and with it the transistor; therefore the bulb goes out.
Then the same process starts all over again.



Diagram 74. Police flasher

#32. POLICE FLASHER

Police cars in pursuit have the right of way on all streets and roads, and they warn other cars that they are coming with flashers and sirens. With this circuit (diagram 75) you can build a flasher that blinks on and off at the same interval as a police car.

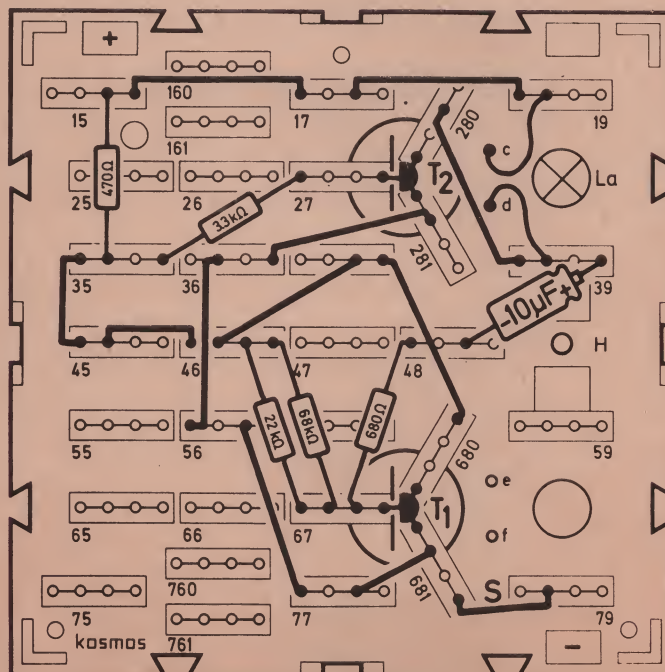


Diagram 75. Construction diagram of police flasher

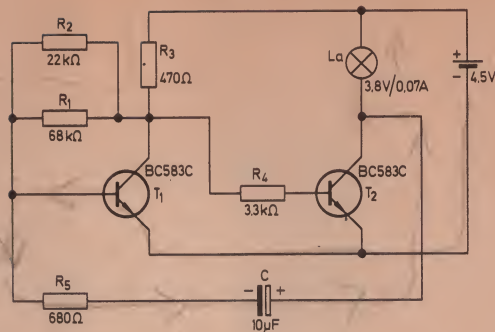


Diagram 76. Circuit diagram for police flasher

How it works

Look at diagram 76. You can compare it easily to the signal light circuit, since there are very few differences. The circuit for the police flasher has been changed to resemble the real thing as closely as possible.

First the interval of light must be shortened. Therefore we connect parallel to one another the $68k\Omega$ resistor R_1 and the $22k\Omega$ resistor as R_2 . The time it takes to discharge the E.C. is substantially shortened because the current now has two possible paths to take.

In order to shorten the time still more, we lessen the value of the resistor at the collector, R_3 , to 470Ω . As base resistor for T_2 (here R_4) we use our $3.3k$ resistor.

To lengthen the dark interval, we set the 680Ω resistor as R_5 between the base of T_2 and the E.C. Now the E.C. needs a bit longer to charge. Your police flasher lights about 2 to 4 times per second.

#33. THE METRONOME



Diagram 77. Playing piano with a metronome

As regularly as the pendulum of an old clock, the metronome on the piano ticks away, so that the piano student doesn't lose time as she plays. It's not easy to play the notes in the rhythm given by the composer. One could compare the metronome with the conductor of an orchestra, who is responsible for making sure that his musicians keep time.

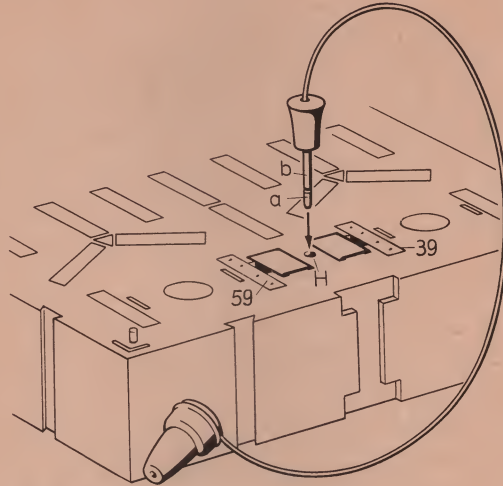


Diagram 78. Ear plug

Before you build the circuit, let's talk about the ear plug (2) and the two jack sockets (18) which you need for your metronome. Our sound unit consists of a plug, which is put into the ear, and of a part in which there are a small magnet and a thin metal plate called a diaphragm. The magnet attracts the diaphragm a bit, so that it's quite easily deflected (made to curve).

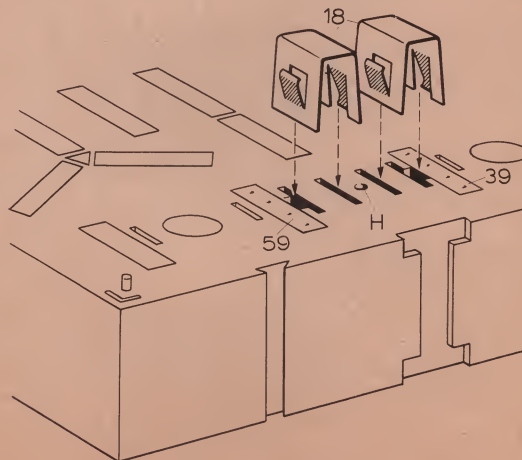


Diagram 79. Inserting the jack sockets

In the center of the magnet is a spool of wire, whose ends are joined to the long wire with the plug switch (the jack) . If electricity flows through the spool, the strength of the magnet is affected. Depending on the current it becomes stronger or weaker, and the diaphragm is either more or less curved. If the current increases and decreases very fast, the diaphragm moves so quickly, that one hears its movement as a knocking sound.

Look at the jack (diagram 78) . It consists of the metal point "a", the shaft "b" and the white plastic attachment. One wire from the spool ends in the metal point, and one ends in the shaft. Between shaft and point you will notice a black insulation, which ensures that when the ear plug is used, no short circuit occurs.

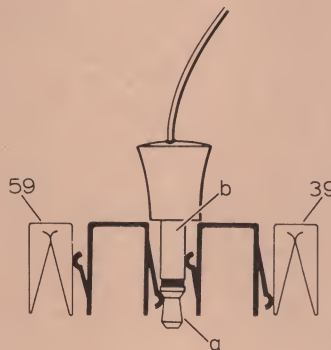


Diagram 80. Inserting the jacks in their sockets

The jack socket conducts the electricity to the jack.

Each jack socket has two metal flaps, one which opens downwards and one upwards. One pointed down is intended to make contact with the tip of the jack, while one pointed upwards should make contact with the shaft. In diagram 79 you will see how the jack sockets should be inserted into the console. On one side should be a flap pointed down, on the other a flap pointed up. If you put them in wrong, the two flaps will both touch either the point or the shaft of the plug - - in either case a short circuit will result. Insert the ear plug into the console at H, deep enough so that the white attachment is resting on the console (diagram 80) . If you turn the console over, you will see how one flap is touching the shaft, and the other the tip of the jack plug. Two flaps on the other side of the jacks touch the snap clips.

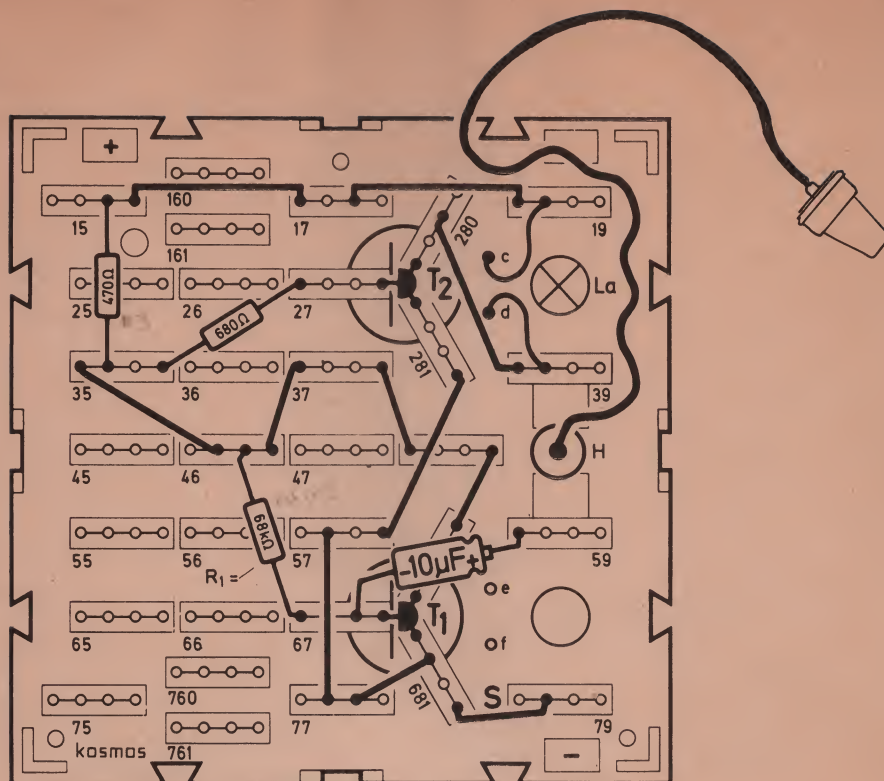


Diagram 81. Construction diagram of metronome

From blinking to ticking

Now build the circuit shown in diagram 81.

Until now we have used the bulb to indicate whether or not power was flowing. Now let's find out if the current variations are strong enough to move the diaphragm in the ear plug, and whether we can hear it.

The most important circuit element is once again R_1 , with which we can change the blinking and ticking rhythm. When you hold the ear plug to your ear and watch the bulb at the same time you will notice that every time the ear plug pops, the bulb goes out.

The current variation must be very great, and the diaphragm is moved enough to make a knocking sound. With a $68k\Omega$ resistor the circuit blinks or ticks every 1 to 3 seconds.

Replace the $68k\Omega$ with the $22k\Omega$ resistor. The tempo increases now to 1 to 3 ticks per second. The bulb lights up at the same speed. You can change the rhythm again, if you use the $3.3k\Omega$ resistor as R_1 . Now it ticks 6 - 18 times per second - a real drum roll!

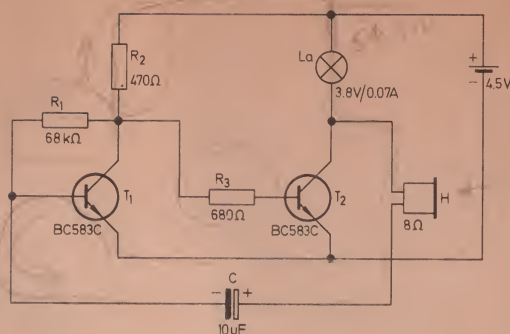


Diagram 82. Circuit diagram for metronome
 $R_1 = 68 \text{ k}\Omega$ or $22 \text{ k}\Omega$ or $3.3 \text{ k}\Omega$

How it works

Take a look at circuit diagram 82. You can compare it with the circuit diagram of the signal light, since both work on the same principle. Only the resistors are different. R_2 has now 470Ω and R_3 680Ω .

The essential difference between the two circuits is the addition of the earplug at the positive pole of the E.C. As soon as the charging current begins to flow into the E.C., the bulb goes out and the diaphragm is deflected so much that it pops in the ear plug.

If you want to use this circuit as a metronome when you play the piano, all you have to do is to use a resistor as R_1 which suits the tempo of your music.

#34. FROM TICKING TO TONES

So now we've seen how we can make sounds with our electronic kit. With the metronome we were able to see that the rhythm of light and sound spurts was the same.

With this new circuit we will experiment to see how ticking can go through seven steps to become tone, when we rearrange our resistors carefully.

For this circuit you don't need your bulb. Insert both the bulb connection wires into 19, since this contact will not be receiving any power. Although the bulb is no longer shown in the diagrams, you can leave it in the console.

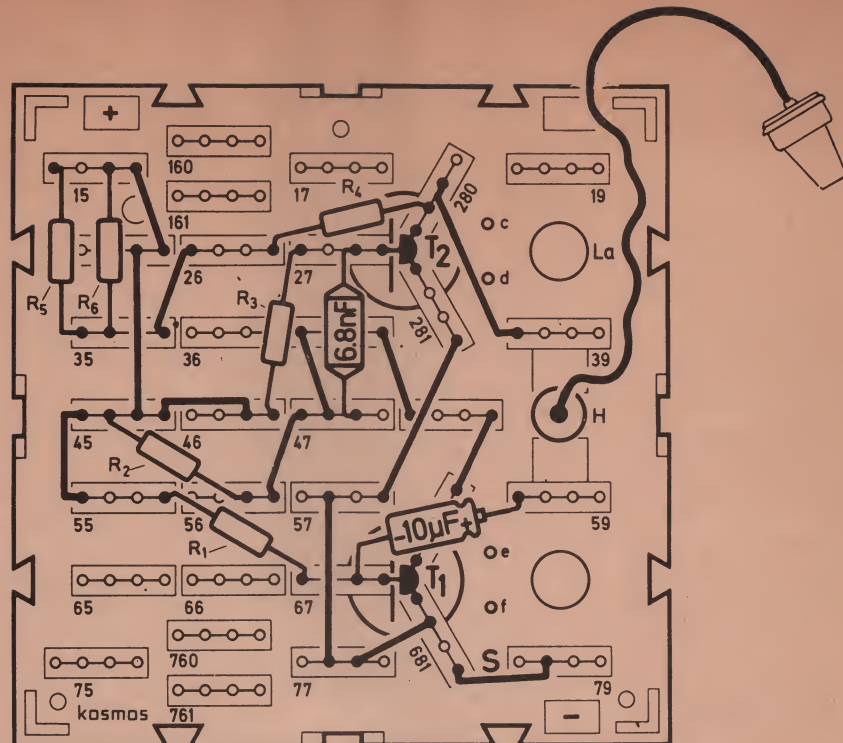


Diagram 83. Construction diagram: from ticking to tone

Build circuit 83. The resistors 1 to 6 are indicated in a table (diagram 84) , and the first time you build the circuit, follow line a. In the ear plug you will hear a fast ticking.

Line	C ₂ in x position	R ₁	R ₂	R ₃	R ₄	R ₅	R ₆	frequency
a	--	68k Ω	3.3k Ω	560k Ω	bridge	680 Ω	--	5-9 Hz
b	--	22k Ω	3.3k Ω	560k Ω	bridge	680 Ω	--	17-33 Hz
c	--	22k Ω	3.3k Ω	68k Ω	bridge	680 Ω	470 Ω	36-44 Hz
d	r	22k Ω	3.3k Ω	68k Ω	bridge	--	470 Ω	60-67 Hz
e	r	22k Ω	3.3k Ω	68k Ω	bridge	680 Ω	--	102-112 Hz
f	r	22k Ω	3.3k Ω	68k Ω	470	680 Ω	--	168-238 Hz
g	r	22k Ω	680 Ω	68k Ω	bridge	3.3k Ω	--	475-525 Hz

Diagram 84. Resistor table

How it works

Now let's take a look at circuit 85. At first sight it seems to work like the signal light. The fact that R₁ no longer leads to R₂, but rather directly to the positive pole of the battery, has little effect on how it works. We replaced the bulb with a combination of resistors - R₄, R₅ and R₆, since we realize that the ear plug is enough to indicate the flow of electricity into the E.C. The current flow to the base of T₂ has been changed--

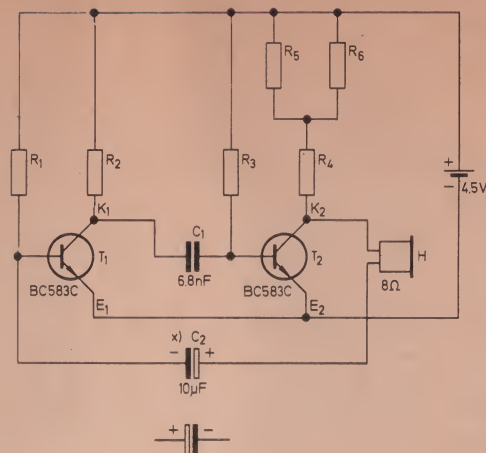


Diagram 85. Circuit diagram: from ticking to tone

x) C_2 should be reversed when "x" appears in the table

it now flows from the positive pole of the battery via R_3 , and from K_1 via C_1 .

Let's begin our description with the moment in which T_2 begins to conduct. (Note: in our manual a "conducting" transistor is the same thing as an "open" transistor). The positive pole of C_2 is connected to the negative pole of the battery via H, K_2 and E_2 . Its negative pole "sucks" at the base of T_1 , so that T_1 closes. Now the current from the positive pole of the battery flows via R_2 into C_1 , and further through the base-emitter route of T_2 to the negative pole of the battery. C_1 is charged.

At the same time C_2 - as in the case of the signal light - discharges its battery charge through R_1 , and then has a tendency to recharge backwards through R_1 . A new feature in this circuit is that C_1 , "sucks" at the base of T_2 , which closes the transistor. The connection between K_2 and E_2 is broken. Now C_2 has its positive pole connected to the positive pole of the battery by a route through the earplug and the resistor combination R_4 , R_5 and R_6 . The flow of this current is what you hear in the earplug as a pop. Then the current moves from the negative pole of C_2 , through the base-emitter route of T_1 , to the negative pole of the battery.

In the meantime C_1 discharges its battery current via R_3 . As soon as it is discharged in this way, C_1 tries to charge itself backwards. Then T_2 starts to collect again, and everything starts all over.

Because the two circuit levels which belong to T_1 and T_2 are built with differing resistors and capacitors, one transistor conducts longer than the other one.

Because of this it can happen that C_2 loads for too long from the wrong direction, and then the danger arises that the capacitor will break. Then we have to release its poles, that is, we must turn it around so that its positive pole lies toward the base of T_1 and its negative pole toward the earplug.

If you replace and juggle all the resistors as shown in the table (diagram 84), the ticking will become faster and faster. You'll hear rattling and whining until finally the noise turns into a relatively high musical tone.

Reverse the poles of C_2 as soon as you see an "r" in the second column of the table, for then it has gotten to a point where the E.C. is being loaded from the wrong end for too long a time. The column on the right of the table gives the tone frequency - f in the physical measurement H (Hertz), which means cycles or vibrations per second.

Now the unstable multivibrator is functioning as an "audio-frequency oscillator".

#35. MORSE CODE

In 1840 Samuel Morse had a very bright idea. He coded the letters of the alphabet into a system of dots and dashes which could easily be transmitted by long and short tones. You can see just how good Morse's idea was when you realize that it doesn't matter whether the sender writes his message in Japanese, English or German. The receiver only has to write down letter by letter the text of the message, even if he doesn't understand the language in which it is sent. If the telegram wasn't in morse code, but was sent instead by radio, the receiver could write it down only if he understood the language.

Perhaps you have already found a short-wave station on your radio where you hear a rapid succession of short and long tones. You might have thought you were hearing static, or else some ham radio operator was disturbing the air-waves. In reality it was the world-wide system of telegraph services which you had caught on your radio band.

You need a lot of practice to understand a morse code message. You have to be able to automatically recognize "dot dash dot" (the letter R) or "dash dash" (M),

etc. But every telegraph operator started out small, and we'll do the same.

Build circuit 86. The morse sending device is a tone generator with resistors arranged to make a buzzing sound most favourable for transmission of code. The key which will trigger a tone signal is placed close to the battery connection (diagram 87). If you press and hold, you will hear a long tone; if you press and release, a short tone. Now all you have to do is to learn from the following table which signal belongs to which letters or numbers, and then you can start transmitting code.

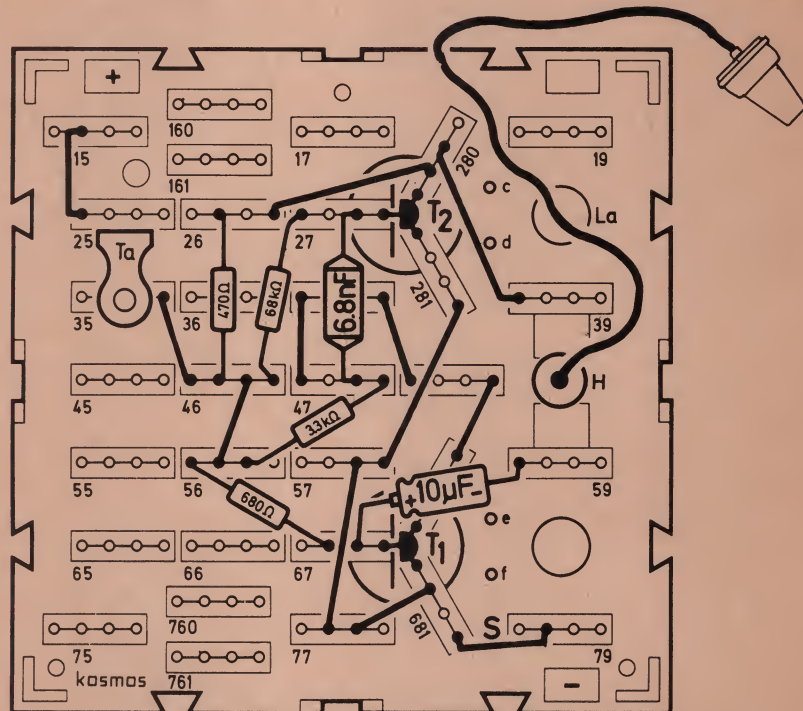


Diagram 86. Construction diagram of morse code sender

- 1 The following letters consist either solely of dots or solely of dashes:

. e	- t
.. i	-- m
... s	--- o
.... h	---- ch

- 2 For the following letters dots and dashes are mixed:

. n	.. u	._. r
_. . d	... v	_. . k
. ... b	.. l	_. _ w
._ a	.._ f	_. _ g

3 The others are harder to remember:

— . . — x	. — — . p
— — . . z	. — — — j
— . . . c	— . — — y
	— — . — q

4 Numbers and punctuation:

1 . — — —	6 —
2 . . — —	7 —
3 . . . —	8 — — . . .
4 —	9 — — — .
5	0 — — — —

question mark	. . — — . .	
period	. — . — . —	
comma	— — . . — —	
open quotation	— . — . —	
close quotation	. — . — .	
bracket	— . — . — —	
dash	—	
hyphen	— —	
double dash	— —	
understood	. — .	
error		(8 dots)

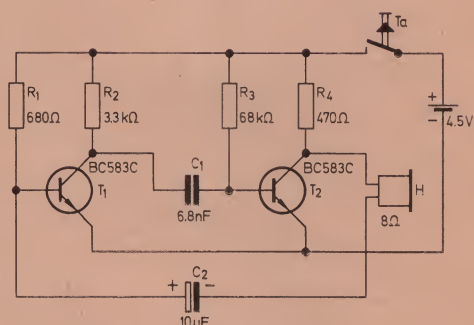


Diagram 87. Circuit diagram for morse code sender

#36. LEMON BATTERY WITH BUZZER

Until now we have used three batteries with a total e.m.f. of 4.5V as source of power for our electronics kit. Moreover it was mentioned that electrical potential is measured with a voltmeter. Where does the expression "volt" come from? The measurement was named in honour of the Italian physicist Count Alessandro Volta, who invented the first usable battery around 1800.

We will test the invention of Count Volta with our lemon battery to see if our circuit works with a volta cell.

Diagram 88. Lemon-powered buzzer.

Diagram 88. Lemon-powered buzzer

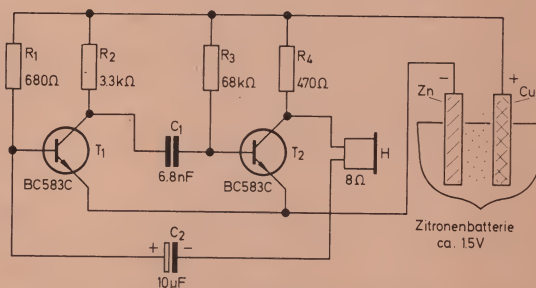


Diagram 89. Circuit diagram of a buzzer with lemon battery

62

The juicier the lemon, the more clearly you will hear the tone.

The lemon battery will work better if you wrap the metal strips in newspaper so that two thicknesses of paper lie between them (diagram 90) . Drip lemon juice over the whole thing, until the paper has absorbed as much as possible. Of course it is important that the paper between the strips is good and damp - - now we see that Count Volta's cell is sufficient to supply our circuit with electricity. The lemon battery has about 1.5V potential, so that the tone is much weaker than if you had connected 681 to the negative, 46 to the positive pole of the built-in battery - - for our three batteries have a total potential of 4.5V.

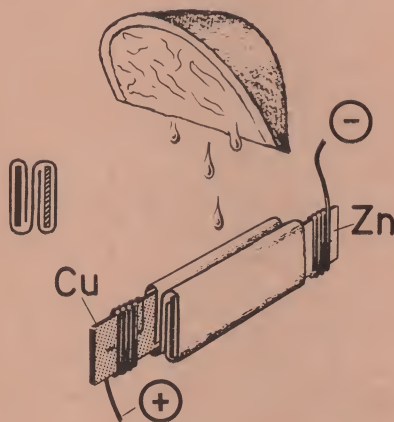


Diagram 90. Volta cell

#37. POLICE AND FIRE SIGNAL

Perhaps you have seen movies in which a European police siren blares out during an exciting chase or race to a fire. It's even possible that, if you live in a large North American city, the "hee haw" siren is used where you live.

Build circuit 92. You can use this circuit as part of the signal apparatus for your electric train set if you wish.



Diagram 91. Fire truck

How it works

When you look at circuit diagram 93, you see that the base resistor R_1 is situated, as in the case of the metro-nome, once again between collector and base of T_1 .

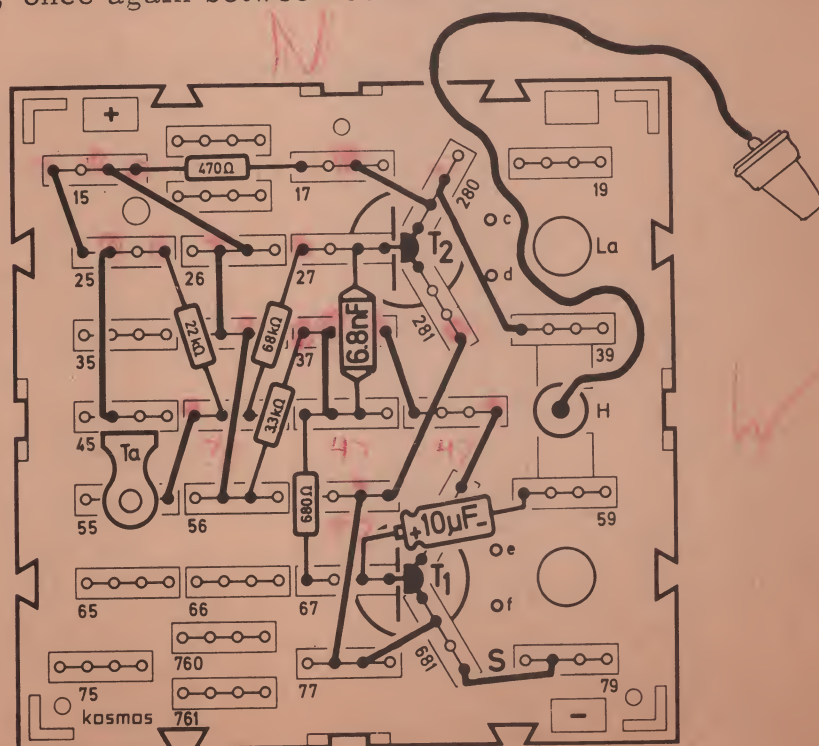


Diagram 92. Construction diagram of police and fire signal

Moreover the values of the resistors used in this circuit are similar to ones used for the morse code sender. Only the base resistor R_4 from T_2 was strengthened. R_3 with $22k\ \Omega$ has been attached to it.

The circuit operates almost exactly like the morse sender, only the key is used here to change the tone frequency. The key is a bridge over R_3 and causes a change in the value of the resistor in the base channel of T_1 - - and therefore changes the length of time it takes to unload C_1 . So the rate of vibration in the multivibrator changes too, and with it the tone frequency.

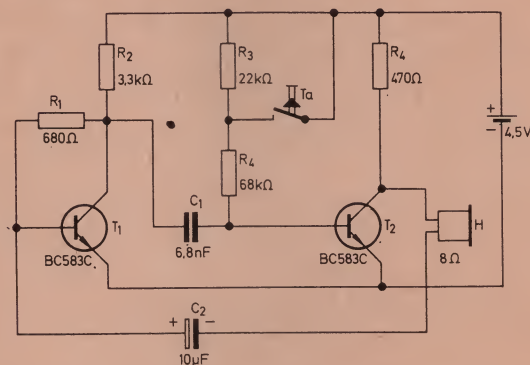


Diagram 93. Circuit diagram for fire siren

Simple electronic organs build whole tonal scales on this principle.

#38. DARLINGTON AMPLIFIER FOR RECORD PLAYERS

It was an old dream of the human race to record the spoken word - - but it wasn't until 1877 that Edison succeeded in making it come true. He impressed uneven grooves in a revolving plate with a stylus that moved in time to a rising sound wave. If one placed a needle on these grooves afterwards, a diaphragm joined to it would reproduce the original sound waves.

Our earplug has a diaphragm which can produce sound waves. If we feed a current to it which varies in the rhythm of sound waves, it transforms the electricity into audible sound. Crystal microphones or crystal systems from recorders send out such power. Unfortunately the power that comes from such a system isn't strong enough to move the diaphragm in the ear plug. Therefore we must "amplify" the tonal current pattern. For this we use our Darlington amplifier.

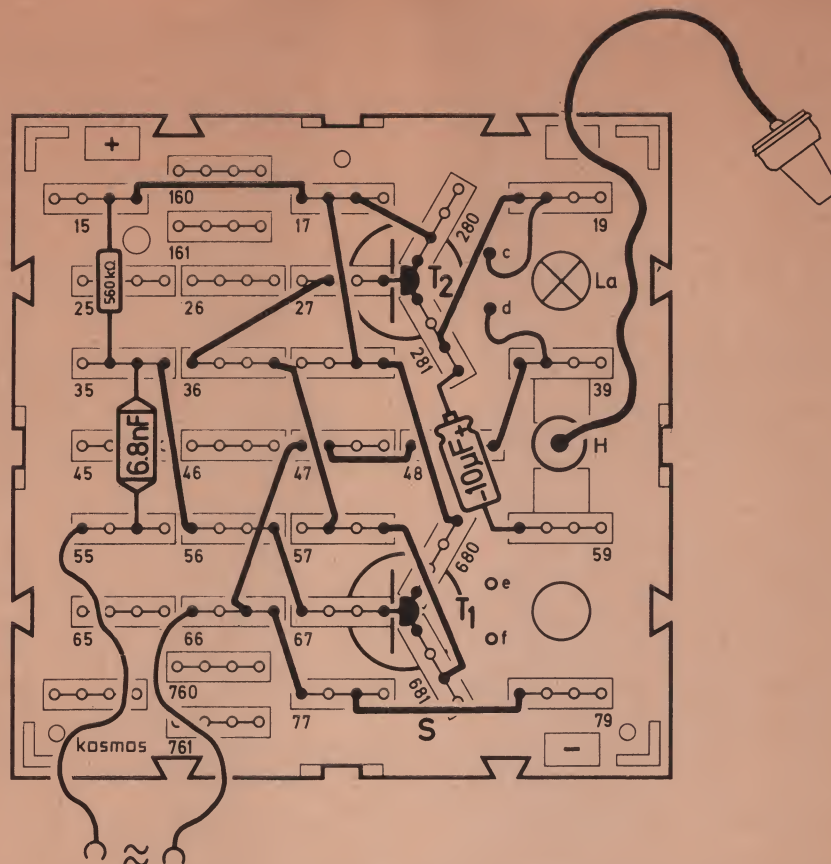


Diagram 94. Construction diagram of Darlington amplifier

How it works

Build circuit 94. Look at circuit diagram 95. R ensures a weak base stream that will hold the base gate of T_1 wide enough open so that it can move in both directions (ie back towards a closed position or wider open) .

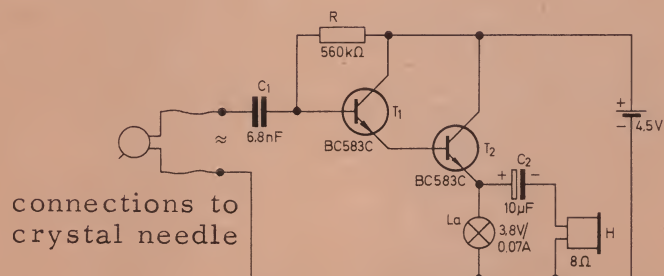


Diagram 95. Circuit diagram for Darlington amplifier

If we add to this base current the weak tonal current pattern via K_1 , the current moves to the rhythm of soundwaves. The base gate will swing in time too, and hence the big "lock gate" of the emitter. So the much stronger emitter current flows in time with the sound wave current. In this way we receive a stronger (ie "amplified") tonal current pattern. In case it's still

too weak, we use the emitter stream of T_1 as the base stream of T_2 - - and the emitter stream of this transistor flows through the ear plug stream where it is transformed into sound again. The way the circuit functions, the base gate of T_2 is exactly half open when a pause occurs in the music and T_1 has no more spurts of current to pass on. It has to be that way so that in reproducing musical sound waves, the gate can move as far as possible in both directions.

This "Darlington amplifier" is named after its inventor who was the first to connect two transistors to one another in this simple way.

In the usual Darlington amplifier no bulb is used, but instead, a resistor. We're not using the bulb here to give light, but rather as an emitter resistor, since it has exactly the right resistance value for our purposes. It would be a mistake to situate the ear plug directly between the emitter of T_2 and the negative battery pole, because the transistor T_2 would burn out.

The spurts of current move through E. C. $_2$ to the earplug and change the magnetism which controls the diaphragm. The diaphragm vibrates and produces sound waves. If you want to attach your Darlington amplifier to a record player, you must attach the two leads from the needle to clips 55 and 66. To do that, insert the two long red wires into clips 55 and 66, and wind their other ends around the two prongs of the plug which contains leads from the needle. If this plug has more than two prongs, you'll have to test until you find the two which produce the loudest reproduction of music. If you hear static behind the music you'll have to reverse the connections of the two long wires on the console, and finally, if that doesn't help, shorten them both. The circuit is so sensitive, that the earplugs buzz if you put your hand near the long wires.



Diagram 96. Darlington amplifier with turntable

#39. DOES SOMEONE YOU KNOW OWN AN ELECTRONICS KIT?

If you know someone who owns another of our electronics kits, you can construct two telegraph stations. Each of you build the morse code sender on his console (diagram 97, and also Chapter 35) . This time the bulbs should be connected, since they will signal one partner that he can expect news from the other. The two systems are connected with three long wires, as shown in diagram 97. Just be careful that wire "t" is in Station A in clip 25 and in Station B in clip 35.

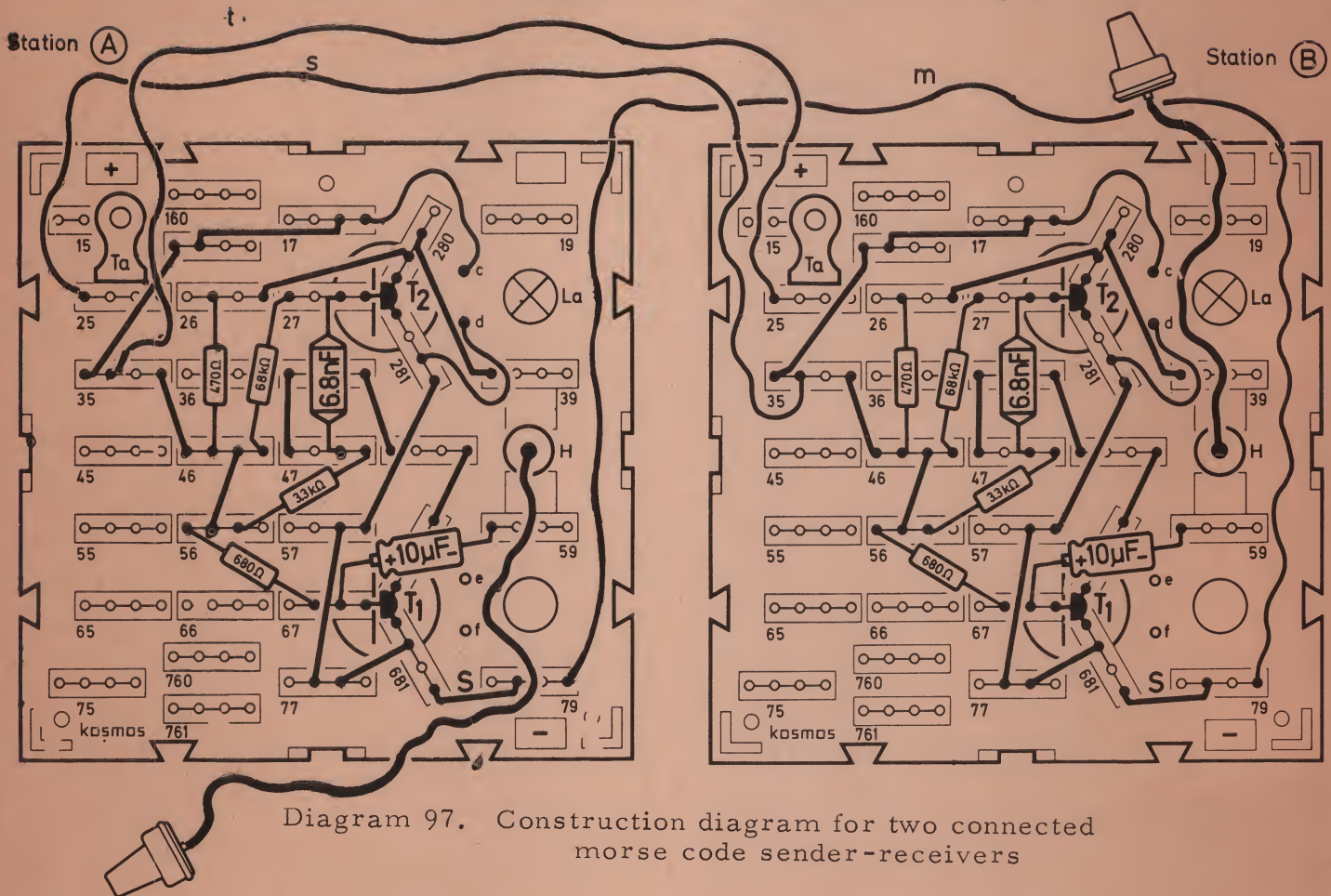


Diagram 97. Construction diagram for two connected morse code sender-receivers

Wire "s", on the other hand, attaches to clip 35 in Station A and 25 in Station B. Wire "m" plugs in at the negative pole of both stations.

Now you can signal your friend that you want to send a telegram.

The power from your device flows through the long wire to the other station, where the lamp lights up and at the same time the ear phone buzzes.

Your friend takes the ear plug and as he listens to your morse code message, he writes it down letter by letter. In the same way, he can answer you.

This is an excellent way to learn morse code by heart!

#40. TWO-TRANSISTOR DIODE RADIO

By using a few new circuit elements, you can build a two-transistor radio on your console. Your radio will give you a glimpse of the fascinating field of radio electronics, which is so important in our modern world of communications.

First you must build the antenna coil which will enable your console to receive radio waves. Take the plastic coil (26) and the wire roll (27) from the kit.

Examine the coil. You will notice that it has five plastic ridges running around a center tube, and four legs on one of its ends. Leaving about 8 inches free at one end of the wire, proceed to wind the wire fifty times around the tube, starting inbetween the first two ridges closest to the plastic coil's legs.

Continue to do this, fifty times each, inside the next two slots as well, as shown in diagram 98.

When you have completed the last turn, leave a 6 - inch lead free at the end and cut the wire.

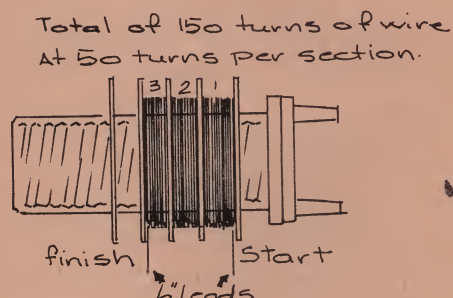


Diagram 98. Winding the antenna coil

Now cut an antenna from the wire roll. This can be anywhere from 2 feet to a yard in length. As well, you will need a "grounding" wire. This wire should connect the console with a conductor which eventually goes into the ground. Some convenient metal conductors which do this are radiators, watertaps, or the metal fingerstop on your telephone dial. Make your grounding wire a length which will allow you to connect the console to one of these things conveniently.

The fourth new circuit element is the crystal diode. The function of this part, as we will soon see, is to filter out the sound signal contained in an electrical current from a radio wave. The diode is a rectifying element, to be connected in the right direction.

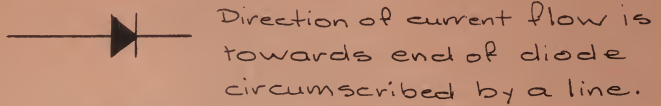


Diagram 98a. Crystal diode

Now build circuit 99.

To tune the radio, take ferrite slug (28) from your kit and screw it into the center of the antenna coil. Adjust the tuning by moving the screw up and down inside the coil with your utility tool. Connect the antenna into clip 65, and grounder into clip 76. Find four holes marked p, q, r, and t on your console, and insert the legs of the antenna coil into them.

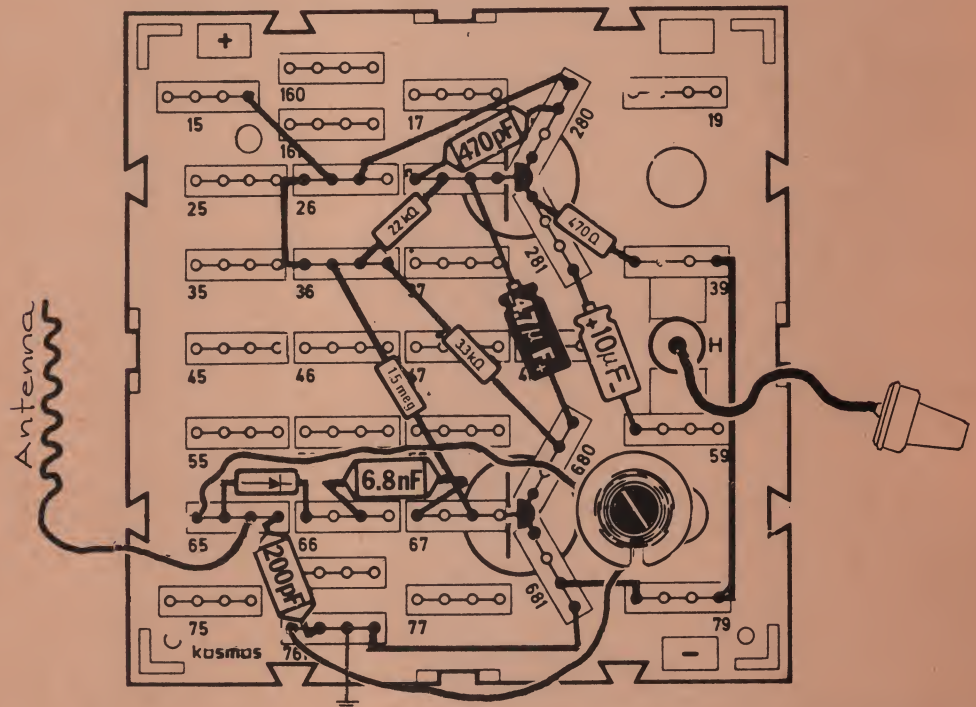


Diagram 99. Construction diagram for two-transistor diode radio

You will find that your radio is capable of receiving stations in the 600 to 900 kilocycle frequency range, which is about half the range of an AM radio. If you want to receive a station with a higher frequency on your AM band, you can do this by removing 10 to 15 windings from your antenna coil.

How it works

Now look at circuit diagram 100.

The circuit can be separated into three segments: that of radio receiver, sound voltage amplifier, and sound power amplifier. It operates as follows.

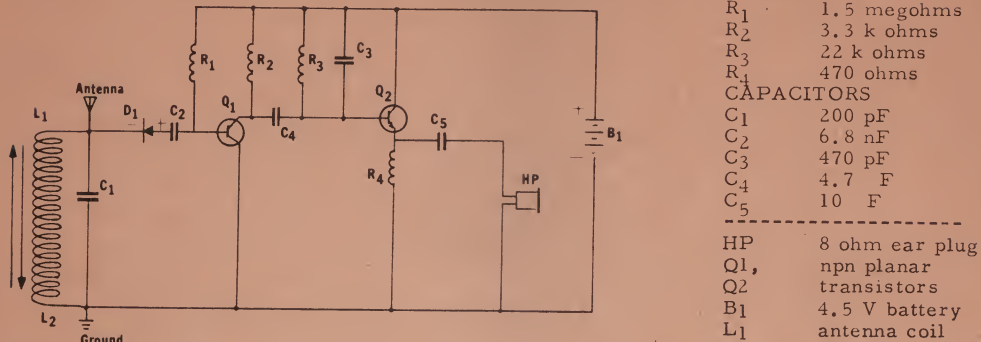


Diagram 100. Circuit diagram for two-transistor diode radio

The antenna coil L1 and the capacitor C1 form a resonant circuit, which, much like a tuning fork, only responds to one vibration frequency. Unlike a tuning fork, this resonant circuit responds to electrical vibrations produced by radio stations. These electrical vibrations are everywhere, and produce tiny electrical currents and voltages in any metal object. A long metal wire, such as your antenna, therefore, converts this "radio wave field" into electrical vibrations. When the antenna wire is connected to L1 and C1, the electrical vibrations make this resonant circuit "ring", or strengthen the vibrations to which it is tuned, while not responding to other vibrations (other stations) -- much like a tuning fork, which "rings" at only one tone of sound.

These strengthened electrical vibrations are, of course, the radio wave sent out by the radio station, and it has sound information contained within it, which must be separated from the radio waves before it can be listened to. This separating, or "decoding," is the job of crystal diode D1. By passing electrical current in only one direction, it is able to change the vibrating, or alternating, voltage from the radio station into direct current, which flows in one direction only. While this direct current is of no use to us, it does contain the information we want--the sound signal.

The capacitor C1 has the function of blocking off the direct current while passing the sound signal on to transistor Q1. Q1 and its associated parts multiply, or amplify this very weak sound signal thousands of times, so that its voltage is much greater.

The now quite strong sound signal voltage is passed to the second transistor Q2 by C4. While the sound voltage is now quite strong, it lacks something that will allow it to become actual sound. It lacks power. It is the function of transistor Q2 to supply the necessary current. It amplifies the sound voltage, and then passes it on to R4, C5, and the earphone. Electrical current flows through the earphone in step with the sound signal.

The earphone converts electrical power into sound power, and the result is, that by listening through the earphone, you can now hear the sound which--

the radio waves carried to the antenna--
which fed the electrical vibrations to the resonant circuit, or tuner--
which picked out the desired station and passed to the crystal diode--
which decoded its vibrations and passed the sound signal to Q1--
which amplified the signal thousands of times and passed it to Q2--
which added power to the sound signal and passed it to the earphone--
which converted the electrical vibrations to sound vibrations.

#41. TWO-TRANSISTOR REGENERATIVE RADIO

This circuit is designed as a further step to the "Two transistor diode radio", and provides greater station separation and higher sound output.

You must now construct another circuit element. Find some circular object with an approximate 1 inch diameter. Leaving an 8 inch lead, wind the wire 20 times around the object. A bottle cap, or even your thumb, if you can find nothing else, will do.

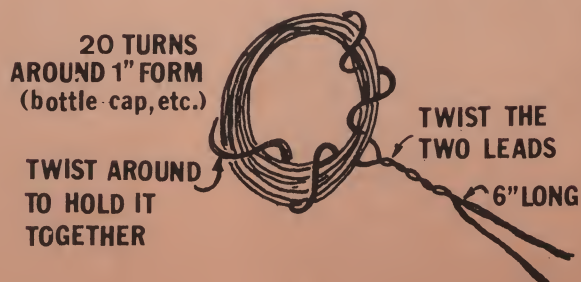


Diagram 101. Winding the feedback coil

Secure the coil by winding the leads around it a couple of times. Leave 6 inches of wire free to plug in to the console. This will be your feedback coil.

Now build circuit 102.

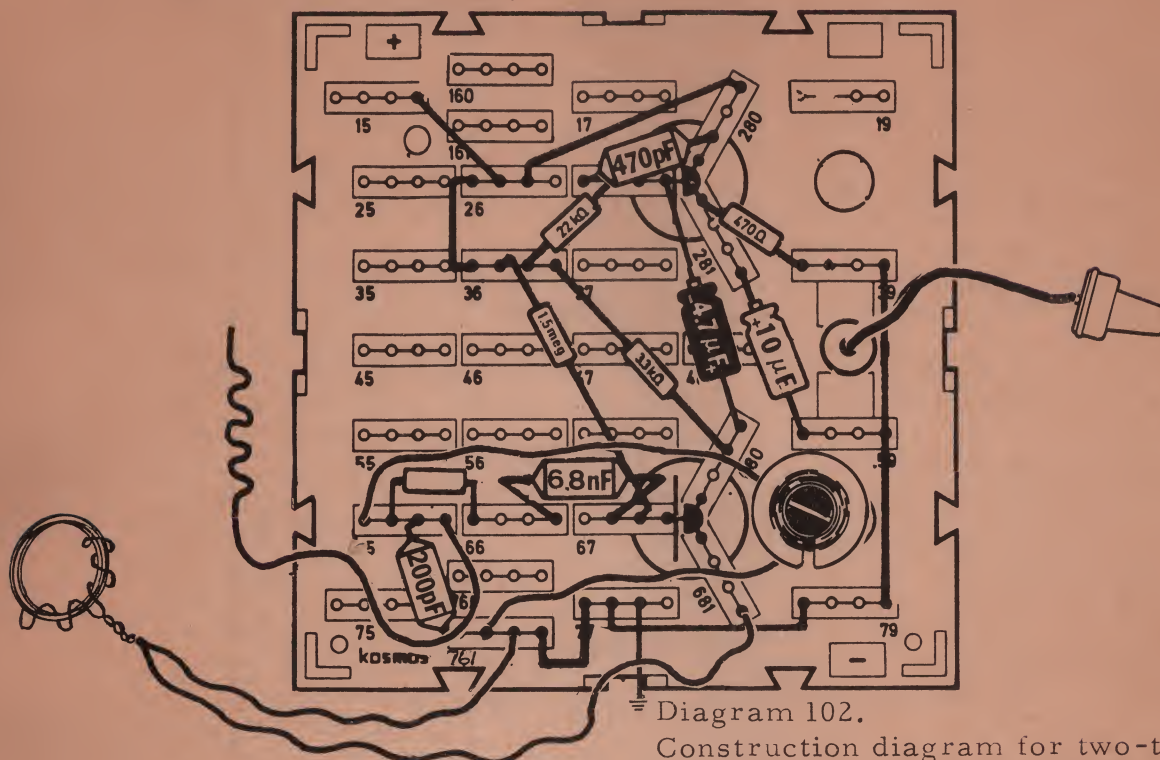


Diagram 102.

Construction diagram for two-transistor regenerative radio

To use the feedback coil

Hold it over the antenna coil L1, and bring the two coils together slowly, while listening to the radio. If the station gets weaker, turn the feedback coil over and try again. Hold L2 at the point where the station is strongest, and just before the radio starts to squeal. When the radio squeals, it is an indication that more energy is being fed back than necessary, and the circuit is unstable.

How it works

The circuit is almost the same as the previous one -- but with one important difference. There is another coil of wire. What does it do?

Let's go back to our familiar tuning fork. Why, after it is struck, does its sound diminish, and disappear? Why doesn't it keep on ringing? It stops ringing simply because some of its energy is continually leaking away, in the form of sound. After all the energy is gone, it stops ringing faster. You can do this by holding a finger against the tines of the fork. Then

the ringing stops right away. Finally, if the tines are covered by your hand, no musical tone can be produced at all. This is because all the energy is taken away at once.

The same thing happens in a resonant radio circuit-- but the energy is lost in other ways. Some goes to the crystal diode decoder. Some is lost in the coil and capacitor itself. The more energy we lose, the less able the circuit will be to receive a station, or tune it in sharply. Our radio circuit is designed to restore this lost energy to the antenna coil.

To understand how, look at the circuit diagram. The transistor does more than amplify sound signals-- C2 also passes some radio waves through, and these get amplified, too. When L2 is connected into the emitter circuit of Q1, these radio waves flow through it. By holding this coil close to L1, some of these amplified radio waves are "fed back" into L1, and make up for some of the lost energy. The closer L2 approaches to L1, the more energy is fed back, until, at one point, all the energy is fed back. At this point, the radio waves are received as strongly as possible, and the sound reaching the earphone is much stronger.

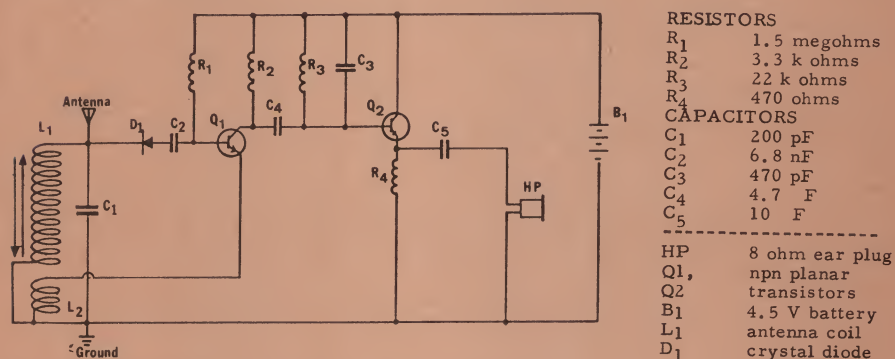


Diagram 103. Circuit diagram for two-transistor regenerative radio

#42. CONCLUSION

You now understand the function of many of the basic circuit elements which are used in industry and at home: a light bulb, a transistor, a resistor, an electrolytic capacitor, a speaker, a diode.

Electricity is behind many mysterious operations-- doors that open and close themselves, record players that switch themselves off, elevators that can "understand" a pushed button, etc. Now you know that electronics is a science which has harnessed electricity to work for us.

GLOSSARY

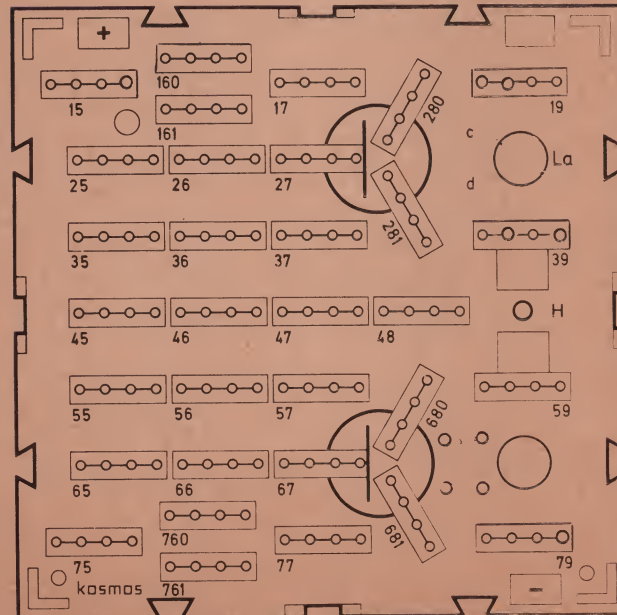
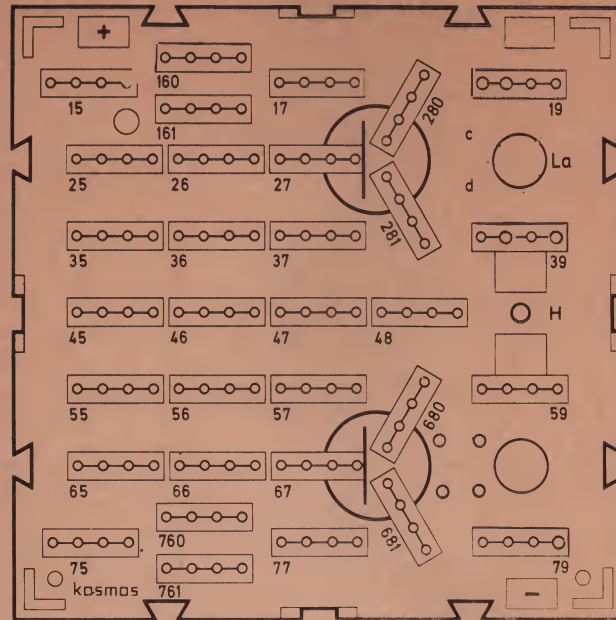
- Antenna:** A mechanism for converting electromagnetic radiation into electrical energy, and vice versa; commonly, a structure designed to transmit and receive radio waves.
- Base:** Stream through which the control signal flows in a transistor.
- Battery:** A group of one or more electric cells connected together for furnishing electric current.
- Capacitor:** A device used in electrical circuits for the temporary storage of electrical charge.
- Cell:** A container holding an electrolyte either for generating electricity or use in electrolysis (often referred to as a battery) .
- Charge:** An excess or deficiency of electrons in a body.
- Circuit:** The complete path of an electric current, usually including the generating device. This complete path is called a closed circuit, and when continuity is broken, it is an open circuit.
- Collector:** Stream through which electricity is supplied from the generating device to the output circuit of a transistor
- Conduct:** To serve as a channel or medium for; transmit, as heat; to act as a conductor, as of heat or electricity.
- Conductor:** A substance or body capable of transmitting electricity and heat, etc.
- Contact:** The junction of two conductors through which current passes; also, a special part made for such a junction or connection.
- Current:** A movement of electricity
- Diaphragm:** A disc capable of vibrating for the production or reception of sound waves (as in the telephone receiver) .
- Discharge:** To remove the electrical energy from.
- Electricity:** A fundamental phenomenon of nature observable in the attractions and repulsions of bodies electrified by friction and in natural phenomena (as lightning) and utilized as a source of energy in the form of electric current.

Electron:	A negatively charged particle that (singly or in numbers) forms the part of an atom outside the nucleus and is of the kind whose flow along a conductor forms an electric current.
Electromotive Force (e. m. f.) :	The energy per unit charge supplied by a current source; this quantity is equal to the source's open-circuit voltage
Electronics:	A science that deals with the principles governing emission of electrons from various solid and liquid materials, and the subsequent control of the freed electrons (by electrical or magnetic means) to perform desired functions--such as amplification, oscillation, and switching.
Emitter:	Stream through which electricity is discharged in the output circuit of a transistor.
Ground, electric:	An electrical connection deliberately made between the earth and a part of an electrical system. Grounding is required to protect persons from electric shocks and equipment from damage, both of which may result from large currents being diverted by a short circuit to an unforeseen path, e. g. through a machine operator or the chassis of the equipment.
Insulate:	To separate a conductor of electricity, heat, or sound, from other conducting bodies by means of something that will not conduct electricity, heat or sound.
Resistor:	A part of an electric circuit that offers resistance to the flow of electricity.
Shock:	A stimulation of human nerves resulting from the flow of electricity through the body.
Short Circuit:	A circuit through a small resistance; especially one which acts as a shunt to a circuit of large resistance.
Switch:	A device for making, breaking or changing the connections in an electrical circuit.
Transistor:	A semi-conductor device which is capable of amplifying electrical power in circuits.
Transmit:	To send out (signals) ; to transfer from one person or place to another.
Volt:	The unit of electromotive force equal to a force that when steadily applied to a conductor whose resistance is one ohm, will produce a current of one ampere.

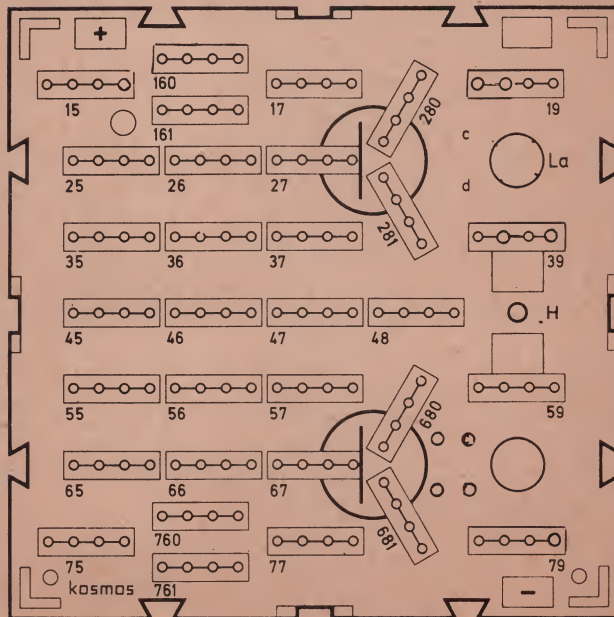
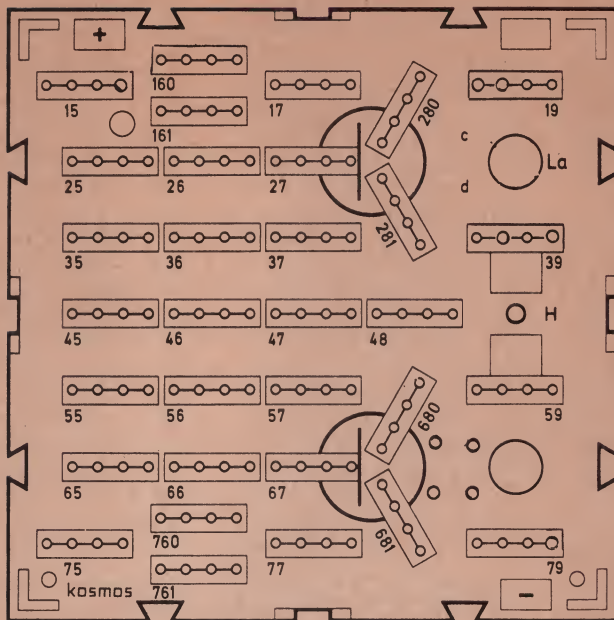
NOTES

NOTES

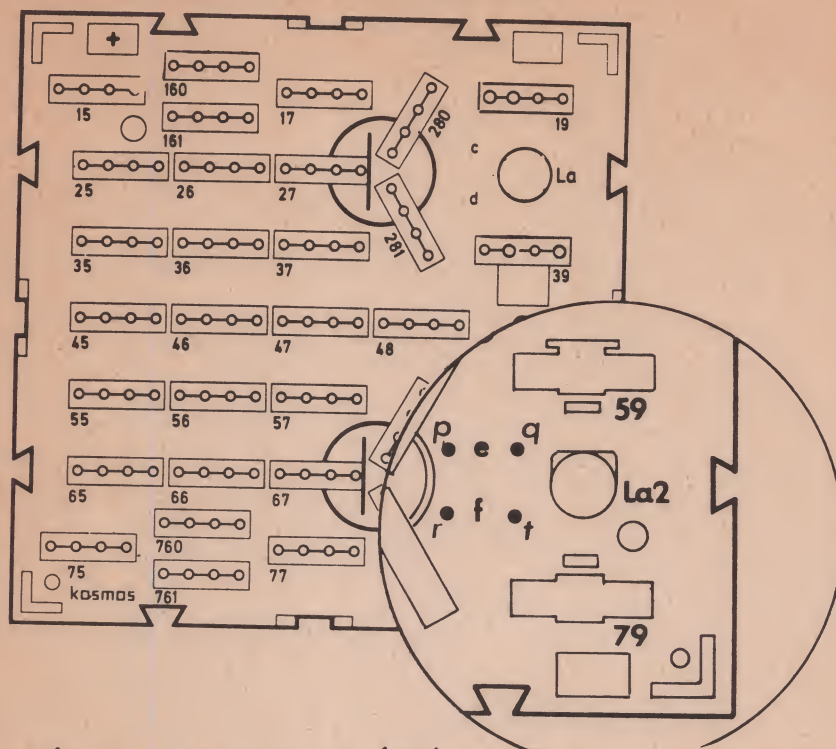
BLANK WIRING SCHEMATICS



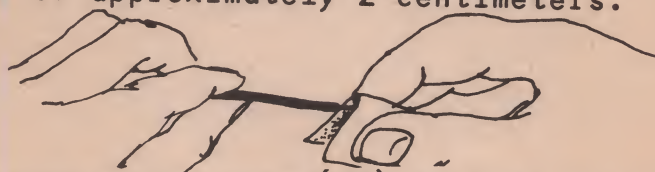
Use these unwired console diagrams to record your own experiments with electrical circuits.



- 1) Holes in the console intended for antenna coil legs are named p, q, r, and t on page 70. You will find them on either side of letters e and f on your console.

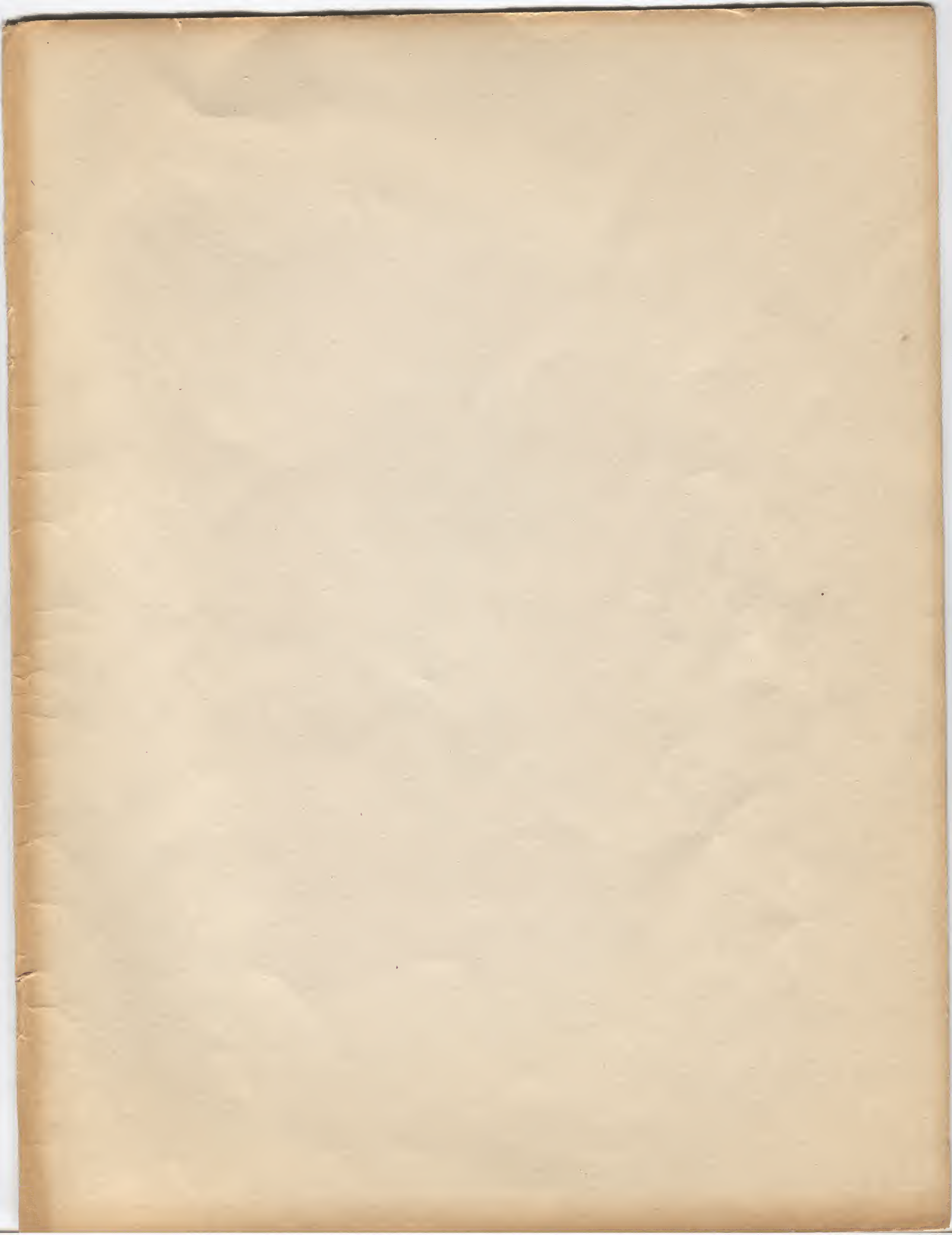


- 2) The wire on your roll (27) is covered with a red insulating varnish. When using this wire for antenna coil, antenna and grounding wire, remove the varnish insulation from the ends which make a conductive contact (ends that are attached to snap clips and ground connection). Remove the insulation from the wire by sanding with a fine grade sandpaper. Remove this insulation to a length of approximately 2 centimeters.



- 3) Use a bulb connection wire (22) to make contact between clips 39 and 79 in both circuits 99 and 102.
- 4) In construction diagram 102, the germanium diode (29) is connected with its positive pole in clip 66 and its negative pole in clip 65.
- 5) Due to commercial variances in components you might find that both radio circuits function better when the diode is removed and the 6.8nF capacitor is connected from clip 65 to clip 67. When this is done the transistor Q1 acts as both a detector and amplifier.

In areas where the signal received is weak, try using a longer antenna wire running vertically along a wall.



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100